AD A102014

LEVEL II

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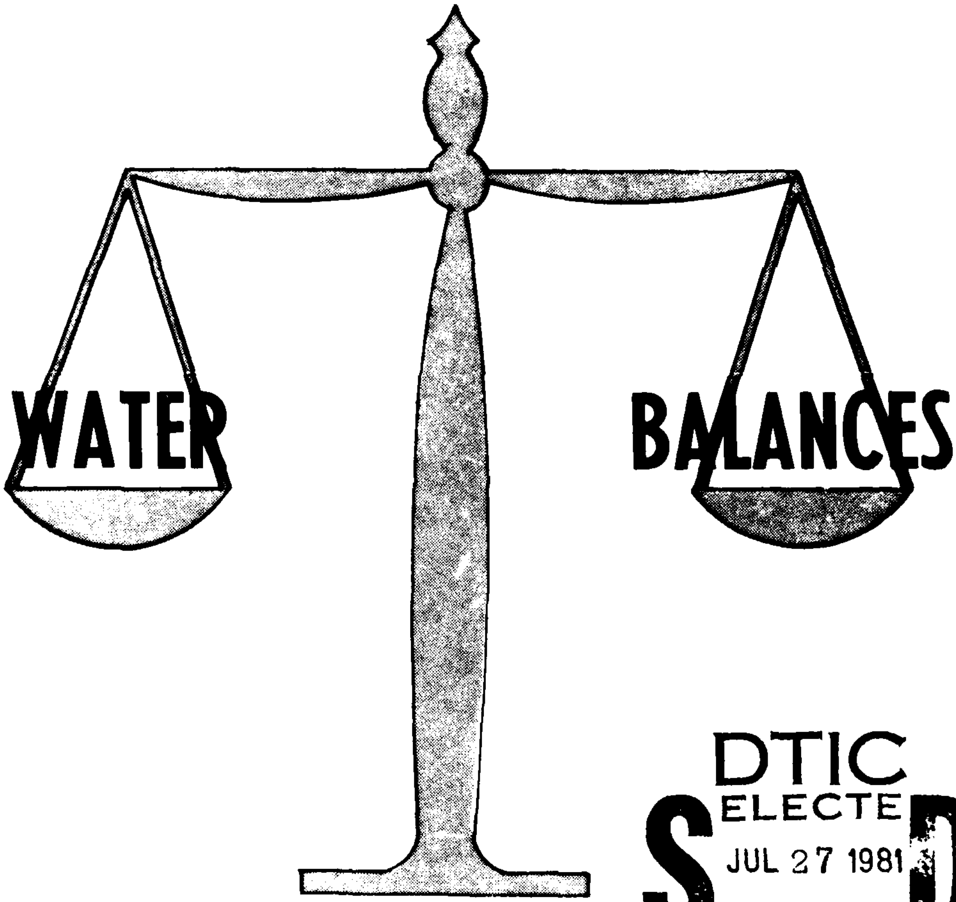
GUIDE MANUAL FOR PREPARATION OF WATER BALANCES



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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A102014	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) GUIDE MANUAL FOR PREPARATION OF WATER BALANCES		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard J. Hayes, Katherine A. Popko and William K. Johnson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Corps of Engineers The Hydrologic Engineering Center 609 Second Street, Davis, CA 95616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE November 1980 13. NUMBER OF PAGES 75
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this publication is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Water balance, water resource management, water resource planning, water supply, conservation.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Wise development and conservation of water resources are founded upon a clear understanding of the resource and its use. Water balances can be an important aid for water resource planning and management because they identify and quantify the resource and its use.

This manual presents: a definition of a water balance; examples of some of its uses; descriptions of the components; a general procedure for computation; specific guidance on collecting supply and use data, and on using methods which estimate components where data are not (CONTINUED)

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available; examples showing how water balance data can be presented; and information on the cost, time, and personnel required for preparing a balance.

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GUIDE MANUAL

FOR PREPARATION OF WATER BALANCES

BY

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CONTENTS

SECTION 1

INTRODUCTION

PURPOSE AND SCOPE

This manual is intended to assist water resource engineers and planners in the preparation of **supply use** water balances. Such balances are an important part of water resource planning and management because they identify and quantify the resource and its use. Wise development and conservation are founded upon a clear understanding of the resource and its use.

This manual presents: a definition of a water balance; examples of some of its uses; descriptions of the components; a general procedure for computation; specific guidance on collecting supply and use data, and on using methods which estimate components where data are not available; examples showing how water balance data can be presented; and information on the cost, time, and personnel required for preparing a balance. Because both supply and use data vary from region to region and even within a region, it was recognized that guidelines such as these must necessarily provide an overall framework within which each balance can vary depending upon the local hydrologic system.

DEFINITION

A water balance is the systematic presentation of data on the supply and use of water within a geographic region for a specific period of time. While this definition is necessarily broad to cover the life cycle of the water resource, its application may be more selective. In a particular watershed only those hydrologic components necessary to achieve the purpose of the

balance are needed and used. For example, precipitation and infiltration data may not be needed if streamflow and ground water data are available. Similarly, municipal return flow may not be included if the quantities are small.

USES OF A WATER BALANCE

Because a water balance includes all principal supply/use components in a hydrologic system there may develop a tendency to ascribe to the balance purposes which it does not serve or associate with it methods which are independent of the balance. It is important, therefore, to understand the purposes which a water balance serves.

Identification of water supply/use problems

A water balance identifies, and where possible quantifies, the sources and uses of water in a geographic region for a specified period of time. Such an identification gives a "picture" of the supply sources: their magnitude, location, and availability over time. It also identifies the water uses by type, purveyor, amount, location, and demand schedule. This type of information is useful in identifying supply and use problems, in assessing their severity, and in examining the supply potential of a region.

Determination of the adequacy of water planning and management data

The amount of data available to adequately describe supply and use will vary. Some water balances may have adequate data because in the region both supply and use are well managed. Another region may have inadequate data. Preparation of a balance provides an opportunity to assess data availability and accuracy, and if the data are inadequate, to pin-point where improvements can be made.

Identification of water conservation opportunities

Knowledge of supply and use as provided through a water balance can assist in identifying opportunities for water conservation and their impact not only

upon demand but upon other parts of the hydrologic system. Because most systems are complex and the supply/use components interrelated, a change in one part (e.g., reduced infiltration) may produce a change elsewhere (e.g., reduced ground water recharge).

Assessment of the impact of resource development

The impact of storage reservoirs, diversion works, well production, deforestation and other types of resource development on other parts of a hydrologic system can be assessed through a water balance. Because a balance considers all principal components of supply and use, changes in their magnitude, location, or timing can be assessed.

The principal criterion for ascribing a purpose to a water balance is that the systematic presentation of data for both supply and use are necessary. If the desired purpose can be achieved with only supply data, or only use data, or with partial data then a water balance which defines the principal components of the total system is unnecessary. Similarly, methods such as low-flow frequency analysis and reservoir yield which go beyond the basic presentation of supply and use data are also beyond the purpose of a water balance.

SECTION 2

WATER BALANCE COMPONENTS

The supply components of a water balance include both the naturally occurring elements of the hydrologic cycle such as streamflow and ground water, and man-related elements such as imported water and return flow. Those components selected for a particular water balance need only include those necessary to identify and quantify the significant sources and uses of water within a given region. Supply components include the following:

(1) PRECIPITATION - water which falls to the earth's surface as rain or snow

(2) STREAMFLOW - water occurring in natural channels; its source may be rainfall, snowmelt, reservoir release, ground water, or return flow.

(3) SURFACE STORAGE - water stored in reservoirs and lakes.

(4) GROUND WATER (Pumpage) - water produced from subsurface storage.

(5) GROUND WATER STORAGE - water occurring in subsurface storage.

(6) IMPORTED WATER - water entering the study area from another basin.

(7) RETURN FLOW - water discharged to a stream or aquifer after use.

(8) SALINE WATER - brackish ground or surface water or ocean water, used primarily as a source for cooling water.

In any particular planning study a different set of components may be applicable. Where adequate streamflow records are available precipitation data are not likely to be needed because the streamflow reflects the results of the precipitation-infiltration-runoff process. In another study precipitation may be an important

input to surface storage and would be included. Similarly, where return flow or saline water are not significant sources of water they could be omitted from the balance. The objective is to include only those supply components which are significant.

The use components of a water balance include the man-related uses such as withdrawals, legal entitlements such as water rights, instream requirements, and natural consumptive uses such as evaporation and seepage.

Components necessary to describe the use of water for a water balance may include the following:

(1) AGRICULTURAL - water withdrawn for agricultural use, primarily irrigation.

(2) MUNICIPAL - water withdrawn by cities and water companies primarily to meet domestic and commercial needs.

(3) INDUSTRIAL - water withdrawn by self-supplying industries.

(4) WATER RIGHTS - legal entitlements to withdraw water.

(5) INSTREAM FLOW - the required amount of flow in a natural stream to maintain acceptable conditions for fish and wildlife, navigation, recreation, hydroelectric power generation, water quality, salinity repulsion, and downstream users.

(6) NATURAL DEPLETIONS

- Evaporation - the loss of water to the atmosphere from land and water surfaces.
- Evapotranspiration - the loss of water by the combined processes of plant transpiration and evaportaion.
- Seepage - the loss of surface water to ground water.

Use components, like supply components, are included to the extent that they make up a significant part of water use in the study area. For example, agricultural use may not be significant in an urban area, or seepage may not be great where stream banks are relatively impervious. In both cases the components may be omitted.

In some cases it may be important to further categorize each component by type of use and/or purveyor. For example, agricultural use may be categorized by crop type and/or irrigation district, industrial use by type of industry and/or industry name, and municipal use by type of use (inside or outside) and/or municipality. The use components may also be subdivided if desired.

Information to quantify supply and use components may be obtained from water purveyors and state and federal water agencies. Water purveyors are the distributors and direct users of water, and include municipalities, irrigation districts, industries, and electric utilities. They are the most important sources of use data. In the content of this manual, purveyors also include the agencies responsible for legal uses of water such as water rights and instream flow. Table 1, "Potential Sources of Supply and Use Data," shows the relationship between purveyors and state and federal agencies, and supply and use data.

TABLE 1

POTENTIAL SOURCES OF SUPPLY AND USE DATA

SOURCE OF DATA	SUPPLY INFORMATION	USE INFORMATION
Purveyors		
Irrigation Districts	Streamflow, ground water, surface storage, imported water, return flow	Agricultural
Industries	Streamflow, ground water, return flow, saline water	Industrial
Water Companies, Municipalities	Streamflow, ground water, surface storage, imported water, return flow	Municipal
State Agencies		
Water Resource Depts.	Streamflow, ground water, surface storage, imported water	Agricultural, Municipal, Industrial
Water Quality Boards	Return flow	In-stream flow
Water Rights Boards		Water rights
Fish & Game Depts.		In-stream flow
Federal Agencies		
United States Geological Survey	Streamflow, surface storage, ground water, ground water storage	Evapotranspiration, Seepage
Water and Power Resources Service	Streamflow, surface storage, imported water	Agricultural, Evapotranspiration, seepage
Environmental Protection Agency	Return flow	Municipal
Fish & Wildlife Service		In-stream flow
Corps of Engineers	Stream flow, surface storage	In-stream flow
Soil Conservation Service	Surface storage	Agricultural, Seepage
National Weather Service	Precipitation	Evaporation
U.S. Department of Commerce		Industrial
Federal Energy Regulatory Commission		Industrial (Steam Electric)

SECTION 3

GENERAL METHOD OF COMPUTATION

SELECT WATER BALANCE BOUNDARIES

Water balances are, in most cases, part of a larger water supply investigation, and as a consequence, boundaries for the balance are the same as those of the larger study. If the study area is large or complex it may be desirable to divide it into subareas and develop water balances for these smaller units. Because of the complexity of some supply/use systems, smaller areas simplify and clarify interactions among components and facilitate a more understandable presentation of the water balance. While the study area for the larger investigation may be based upon geographic, hydrologic, institutional or other boundaries, the boundaries for a water balance should follow hydrologic and institutional boundaries wherever possible. Hydrologic boundaries should be used to encompass the water supply, and institutional boundaries to enclose areas of water use. Typical hydrologic boundaries include:

- all or part of a river basin
- all or part of a ground water basin
- a reservoir or lake

Common institutional boundaries are:

- Standard Metropolitan Statistical Area (SMSA)
- county
- water or irrigation district
- city or town

Hydrologic Boundaries

If a river is the only supply for a particular study area, water balance

boundaries should encompass the supply watershed of the river. If ground water is a supply, all or part of the ground water basin must be considered. Where both a river and ground water serve as the supply it may be desirable to create separate boundaries and develop separate water balances for each supply source. This simplifies data collection, especially for combinations of surface and ground water supply systems where depletions from the former (e.g., seepage) serve as recharge to the latter, complicating simultaneous quantification of components. In addition, the water balance will more accurately reflect water supply conditions if each source is addressed separately, because the variability of each source is an important consideration.

When establishing hydrologic boundaries, it is also desirable to utilize homogeneous sections of a complex supply system. For example, in preparing a water balance for a ground water basin which has variable hydrologeological characteristics, computations will be simpler and more accurate if the basin is divided into sections with farily uniform aquifer characteristics and similar patterns of increasing or decreasing water levels. Later, the sections can be aggregated to show the composite supply from this source.

Data availability helps shape final hydrologic boundaries once the water source has been determined. If the supply source is a river, the location of stream gages is an important consideration. A reliable gage with a long period of record just upstream of the water users' intake is ideal; however, boundaries generally must be extended some distance upstream to include a suitable gage. If no gages exist, estimates of river flow will be necessary and boundaries should encompass that part of the watershed used in the calculations. Dams on regulated rivers are good upstream boundaries since records of releases are usually available.

Institutional Boundaries

The purpose of a water balance often influences selection of boundaries for water use. In some cases the geographic area of water use and the type of use need not be considered. Total quantity withdrawn from each source may be the only use component of concern if the actual type of use does not affect the ability of a source to satisfy current or future demands. In other situations the area related to a particular type of water use must be included within water balance boundaries because detailed water use information is needed. As an example, a balance to determine the adequacy of water data may find data on one type of use, such as municipal, to be fully documented whereas data on industrial use may be limited. A water conservation balance may find a small percentage decrease in agricultural consumption saves significant quantities of water while a similar conservation effort in the domestic sector has less impact. These conclusions would not be possible if types of uses, and therefore the area of water use, were not considered. Boundaries in water data or water conservation balances may be as large as a river basin and several water districts, counties, or municipalities, or as small as an impoundment on a stream and a single industry. Boundaries for a large study area which has limited water use may be reduced to include the local area of water use and just enough of the water source as necessary for data collection and analysis.

Availability of water use data is generally determined by purveyor records, so institutional boundaries will most often encompass water or irrigation districts, municipalities, or counties. Population and economic information from which estimates and projections of water use can be made is compiled for Standard Metropolitan Statistical Areas, used by the U. S. Bureau of Census for planning and estimating purposes. An SMSA usually includes a county or group of contiguous counties which contain at least one central city of 50,000 inhabitants or more, or "twin cities" with a combined population of at least 50,000.

SELECT PERIOD OF ANALYSIS

The time period upon which a water balance is based will vary depending upon the purpose of the balance. Common periods include:

- historic drought period
- recent past period
- future period

Different types of periods may be used for supply and use components in the same balance, although the length of the period should be identical for both components.

Historic drought period

A drought period may be defined in hydrologic terms as a time of decreased streamflow, reduced lake or reservoir storage, or lowered ground water levels. Agricultural, industrial, and municipal activities are most likely to be adversely affected during such a period of low water availability. Therefore, the critical drought in historical records is a useful period of analysis for supply data in a water balance conducted to identify water supply/use problems. The drought chosen may be critical in terms of magnitude (i.e., lowest streamflow, surface storage, or ground water levels on record), or duration (i.e., the longest time of drought conditions). Knowledge of what type of water management facilities exist in the water balance area will help determine the best choice. For example, if a reservoir with a large volume of storage is utilized, a lengthy period of drought will be of more concern than a brief period, even if the surface storage reduction is actually greater in the latter case. The most severe strain on these water management facilities and therefore the most critical water supply problems will be identified if supply data from the extended drought period is used in the water balance.

Recent past period

Recent records of water use reflect current trends in demand based upon current population and water needs. The recent past is useful for identifying water supply/use problems because current demand is usually the highest historical water demand which imposes maximum stress on a water supply source.

The recent past is also a good period for a water balance to determine the adequacy of data for water management, since it is likely that the most current data will be the most complete. For the same reason, this is a good period to identify water conservation opportunities.

Future period

A period of analysis for future conditions is useful for water balances to assess the impact of proposed resource development, such as diversion from a river or pumping from a ground water basin. Such a balance contrasts low water supply with projected water use under proposed development conditions. For example, consider a water balance to assess the impact of obtaining a cooling water supply for a 1,000 MW steam electric plant from a ground water basin. A balance would show whether the required year-round pumping would exceed average annual recharge and deplete the quantity of ground water presently in storage. Some types of resource development, such as construction of a storage reservoir or clearing of a forested area, induce changes in both supply and use components. In these cases a future period of analysis is used for both components.

The three types of analysis periods described above may have any duration: several years, a single year, or part of a year. An analysis period which covers several years is particularly useful for encompassing extended periods of drought, or for studying long-range effects of water use. Part of a year may be the best

duration for focusing on times of high demand, like a growing or canning season, or on isolated periods of water use, as in a winter ski resort. A year is a common duration for a water balance since both supply and use data are usually tabulated on an annual basis. However, there are several types of "years," and one may be more appropriate than another.

Climatic years extend from April 1 to March 31. This represents a period beginning and ending during high runoff conditions for most of the United States. The climatic year begins and ends at a time of year when flows are likely to be high and completely encompasses a period of low flow. This type of year is therefore particularly useful for water balances to identify water supply/use problems.

Water years extend from October 1 to September 30, and usually represent a period beginning and ending during low runoff conditions. Total runoff for a single rainy season is therefore included. Streamflow data is often recorded by water year, so supply data collection may be facilitated if this type of year is chosen.

Calendar years, from January 1 to December 31, do not reflect hydrologic conditions. However, they are a common type of year for which water use is recorded. If the water use data for a particular balance is exceedingly complex, data collection may be simplified by keeping the use data in its original form and converting the supply data to the calendar year.

SELECT LEVEL OF DETAIL

Level of detail refers to the time period represented by the data. Examples are annual, seasonal, monthly, weekly, or daily data. One level of detail should be used consistently for presentation of all components in the water balance if these components or their totals are to be compared.

Selection of the level of detail is influenced by the variation in water supply and use throughout the year. Where water availability fluctuates with the seasons, as with a stream influenced by precipitation, or where water use peaks at certain times of the year, weekly, monthly, or perhaps seasonal data should be used. Annual values may mask seasonal, monthly, or weekly variations; however, they are appropriate for a water balance if water use and availability do not change significantly during the year. An example is slowly increasing domestic use from a ground water basin with large storage capacity. Annual values are also appropriate when it is desired to show long-term trends in supply or use.

Selection of level of detail is further influenced by the duration of the period of analysis. If the past ten years are selected for the period of analysis, collecting data on a monthly or more frequent basis may be quite time-consuming. Annual values could be used to indicate general trends, and monthly data employed for the most recent, or perhaps most critical year. If only part of a year is being studied, weekly data would be appropriate, especially if supply or use fluctuate rapidly and this fluctuation is of interest.

IDENTIFY SIGNIFICANT COMPONENTS

Water balance components were listed and described in Section 2. In a given balance, some of these may be more important than others, since major supply sources and significant uses vary with location. In some areas, such as the San Joaquin Valley in California, agriculture is highly dependent upon ground water. In contrast, surface water is the principal supply source for agriculture near Albuquerque, New Mexico. The City of Albuquerque relies solely upon ground water to fill municipal needs, while in the Metropolitan

Washington, D. C. area, ground water use is currently negligible. Depletions such as seepage from a surface storage system may be high where a reservoir is situated in sandy, permeable material, but insignificant if bottom material is clay. Therefore, thorough understanding of the area is a primary requisite to conducting a meaningful water balance.

For some water balance purposes, it is important to consider potential as well as current sources of supply. To determine the adequacy of data for water management, information on both current and potential water supplies should be gathered. Deficiencies can then be identified and data collection programs instituted before the potential source is developed, since effective management requires a solid data base. For example, ground water is often a little-used resource where surface supplies are adequate, but as water demands increase, this resource could be developed. Proper ground water management requires such information as natural recharge and storage capacity - data which cannot be accumulated quickly.

WRITE WATER BALANCE EQUATION

The general relationship between supply and use components can be expressed in a water balance equation. The components included in such an equation will vary depending upon the supply system and the purpose of the balance. In addition, the basic form of the water balance equation will be different for each of the three major supply systems: streamflow, surface storage, and ground water.

For a stream system without intermediate storage, the water balance equation is:

Downstream Flow = Upstream Flow + Local Inflow - Depletions - Withdrawals

The resultant, downstream flow, is flow available to supply downstream contracts, in-stream flow requirements, or potential development. Upstream flow involves gaged or estimated flows at the upstream water balance boundary. Local inflow should include return flows from agricultural runoff, municipal sewage treatment, etc., if these are significant quantities and enter the system within water balance boundaries. Depletions include natural losses such as channel seepage and evaporation. Withdrawals may include agricultural, municipal, and industrial uses. In-stream flow requirements may also be included as withdrawals.

For a surface storage system, components should be expressed as volumes instead of flow rates. The water balance equation is:

Surface Storage Remaining = Inflow + Storage - Depletions - Withdrawals

The resultant, surface storage remaining, can be compared to the required lake or reservoir storage to determine periods of surplus or deficit supply. Inflow includes significant streamflows entering the water body. Storage may be the surface storage remaining from a previous period or an average value. Depletions represent significant natural losses such as seepage and net evaporation. Withdrawals include water taken from the lake or reservoir for various purposes including reservoir releases.

For a ground water system, the water balance equation is:

Change in Storage = Recharge - Pumpage + Inflow - Outflow

The resultant, change in storage, indicates whether the resource is being depleted (negative change in storage) or replenished (positive change in storage) and the relative magnitude of the change. Recharge represents surface water which percolates to the ground water, and may be either natural or artificial. Natural recharge includes percolation of precipitation, and seepage from streamflow,

lakes and reservoirs. Artificial recharge results from excess irrigation, and water purposely applied to augment ground water supplies. Pumpage includes withdrawal of ground water for various uses. Frequently the net effect of recharge and pumpage is measured by changes in well water levels. Inflow and outflow, which are underflows into and out of a ground water basin, should be accounted for; however, these quantities are often considered equal for lack of specific knowledge.

The water balance equations are useful in describing interrelationships between components and in determining resultant surpluses and deficits in a system. Most applications of these equations will be to complex systems where each component is made up of many parts - some known, some unknown; some relatively accurate, others only rough estimates. When combining these data for the water balance equations the resultant values will only be approximate and the two sides of the equation are not likely to be equal. The value of writing such an equation is in identifying the components and their interrelationship and not necessarily in equating one side to the other in a mathematical sense.

Because the equations help organize data, they are also useful in a water balance to determine the adequacy of data for water management even though actual calculation of a resultant is not necessary. This type of water balance is performed to denote deficiencies in data records so that future data collection efforts can focus on filling in the gaps. The water balance equations aid in the systematic presentation of data so that significant deficiencies will be obvious when the collection is complete.

QUANTIFY WATER BALANCE COMPONENTS

Actual procedures for calculating various components are discussed in the next section; a few basic principles will be mentioned here.

The best data for development of a water balance are actual measurements taken in the area for which a water balance is being prepared. Some examples are records of streamflow from local gages, measured changes in local ground water levels, and metered withdrawals from a supply source. Data which is not measured, or data from outside the area, such as state or regional averages or generalized estimates, may not reflect actual conditions as accurately, but often are the only data available and must be used.

When gathering data from many sources, it is likely quantities will be presented in different units - as flows in cubic feet per second, acre-feet per day, gallons per minute, and million gallons per day, or as corresponding volumes. Metric units may also be in use. All supply and use components should be quantified in consistent units for the water balance to have meaning and for ease in comparing the relative magnitude of the components.

INTERPRET RESULTS

A water balance, because it utilizes data of a variety of types, sources and accuracy, cannot be expected to be a precise accounting of water supply and use. Nor can it be expected to be a complete description of a surface or ground water system. The quantities associated with each component and the summary quantities of supply and use or surface and ground water are estimates - hopefully best estimates - of their magnitude. They should not be expected to "close" or "balance" in a precise mathematical sense.

Differences between inputs and outputs may be caused by various factors. In the water balance conducted as part of the Albuquerque Greater Urban Area Water Supply Study (39), the differences between inputs and outputs for each year were due to several possible factors:

- oversights in identifying all inputs.
- overestimation of some outputs .
- use of averages and constant percentages in calculations without considering annual variations in climatic factors.
- use of a calendar year as the period of analysis, which does not account for seasonal fluctuation.
- estimations and assumptions required when boundaries of the data collection network and the water balance area did not coincide.
- inability to account for complex interactions between surface and ground water systems.

A water balance reflects current knowledge and understanding of water supply and use, and any "imbalance" may be regarded as a measure of ignorance about the system. The significance of an imbalance is a matter of judgement, and depends upon the purpose of the balance.

SECTION 4

DETERMINATION OF PRINCIPAL WATER BALANCE COMPONENTS

The purpose of this section is to identify sources of water supply and use data and to suggest methods of computation when data are unavailable or incomplete.

SUPPLY COMPONENTS

Precipitation

Precipitation data may be needed for the preparation of water balances when ground water recharge and net lake evaporation estimates are required. Precipitation data in the form of tables, maps and computer readable tapes are available from the National Climatic Center in Asheville, North Carolina. A useful source of precipitation data for water balance applications are the National Climatic Center annual state data summaries entitled Climatological Data, Annual Summary (27). These reports are usually available in National Weather Service and Corps of Engineers offices. They contain observed monthly and annual precipitation data for National Weather Service stations and cooperating substations. In addition, this report series lists normal monthly and annual precipitation data for long term stations. Also of value is the Climatic Atlas of the United States (26), which shows precipitation, evaporation and other climatic data in map form.

Methods to estimate average aerial precipitation from gage data include the Thiessen polygon and Isohyetal methods. These methods are described in IHD, Volume 4, Hydrograph Analysis (43) and in standard texts such as Handbook of Applied Hydrology (6).

Streamflow

Streamflow in most water balance applications is a principal source of supply. Streamflow data represents the hydrologic response of a watershed, incorporating the effect of many parameters such as precipitation, snowmelt, evaporation and infiltration, for which data are generally unavailable.

Streamflow data. Streamflow data are generally available from local purveyors and state and federal agencies. The primary streamflow data collection agency in the United States is the United States Geological Survey (USGS). Their publications and computerized data files contain data collected by more than 300 agencies at about 16,000 locations.

USGS streamflow data is published on a yearly basis, by state, in the report series entitled Water Resources Data for (State), Part 1, Surface Water Data and on a five year basis by hydrologic region in the USGS Water Supply Paper Series, Surface Water Supply of the United States. Both report series contain the same type of streamflow data. A typical example of streamflow data from a USGS Water Supply Paper is shown in Figure 4-1.

06329500 YELLOWSTONE RIVER NEAR SIDNEY, MONT.

LOCATION.--Lat 47°40'42", long 104°09'22", in SW¼NE¼SW¼ sec.9, T.22 N., R.59 E., Richland County, on left bank at Montana Dakota Utilities Co. powerplant, 0.2 mile downstream from bridge on State Highway 23, 2.5 miles south of Sidney, 5.0 miles downstream from Fox Creek, and 30 miles upstream from mouth. Apr. 4, 1952, to Nov. 19, 1967, at site 4.5 miles upstream.

DRAINAGE AREA.--69,103 sq mi. Area at site 4.5 miles upstream, 68,812 sq mi.

PERIOD OF RECORD.--October 1910 to September 1931 (published as "at Intake"), October 1933 to September 1970. If monthly figures of diversion to Lower Yellowstone Canal at Intake are added to records at this site, records equivalent to those published as Yellowstone River at Glendive (1898-1910, 1931-34) can be obtained. Monthly discharge only for some periods, published in WSP 1309. Monthly figures of diversions into Lower Yellowstone Canal prior to 1951 published in WSP 1309, 1951-60 published in WSP 1729, 1961-65 published in WSP 1916.

GAGE.--Water-stage recorder. Datum of gage is 1,881.3 ft above mean sea level (levels by Corps of Engineers). Apr. 4, 1952, to Nov. 19, 1967, water-stage recorder at site 4.5 miles upstream at different datum. See WSP 1916 for history of changes prior to Apr. 4, 1952.

AVERAGE DISCHARGE.--58 years, 12,910 cfs (9,353,000 acre-ft per year).

EXTREMES.--Maximums and minimums (discharge in cubic feet per second, gage height in feet) for the water years 1966-70 are contained in the following table:

	Maximum			Minimum daily	
Wtr yr	Date	Discharge	G.H.	Date	Discharge
1966	June 5, 1966	28,000	a11.37	Sept.16, 1966	2,360
1967	June 20, 1967	82,600	16.86	Dec. 5, 1966	3,600
1968	June 13, 1968	71,300	15.83	Dec. 25, 1967	5,000
1969	Mar. 21, 1969	-	b21.00	Jan. 4, 5, 1969	4,000
1970	June 13, 1970	61,000	14.75	Jan. 12, 13, 1970	2,500

a Maximum gage height for year, 13.34 ft Mar. 17, 1966, backwater from ice.
b Backwater from ice.

Period of record: Maximum discharge observed, 159,000 cfs June 21, 1921 (gage height, 12.6 ft, site and datum then in use); maximum gage height observed, 21.85 ft Mar. 22, 1947, site and datum then in use (backwater from ice); minimum discharge, 470 cfs May 17, 1961 (gage height, 2.73 ft, site and datum then in use).

REMARKS.--Records good except those for winter periods, which are poor. Some regulation on tributary streams. Diversions for irrigation of about 1,250,000 acres above station. Lower Yellowstone Canal diverts from left bank in NW¼ sec.36, T.18 N., R.56 E., at Lower Yellowstone diversion dam at Intake about 36.6 miles (revised upstream for irrigation of about 52,000 acres, of which about one-third is above station. Water-quality records for the water years 1966-70 are published in reports of the Geological Survey.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1965 TO SEPTEMBER 1966

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12,700	9,900	5,500	4,500	4,200	4,900	10,600	5,980	23,000	12,800	5,310	3,260
2	12,800	9,690	6,000	5,000	4,200	4,900	7,150	6,200	24,800	12,900	5,140	3,050
3	13,900	9,500	7,000	5,300	4,500	5,000	6,340	6,090	26,600	14,000	4,610	2,720
4	14,100	9,450	8,000	5,600	5,000	5,000	6,060	6,030	26,400	14,400	4,280	2,520
5	14,100	9,380	7,500	6,000	6,000	5,000	5,950	5,710	26,600	13,400	4,020	2,460
6	13,900	8,630	7,400	5,500	7,500	5,000	6,030	5,210	23,000	13,600	3,880	2,580
7	13,600	7,380	7,300	5,000	8,200	4,900	5,950	4,380	20,500	12,500	3,820	2,780
8	13,300	6,120	7,200	4,500	8,300	4,900	5,790	4,500	17,900	11,000	3,700	2,740
9	13,000	5,780	7,100	4,000	8,200	4,800	5,490	5,790	15,800	9,620	3,750	3,030
10	12,700	5,750	7,000	3,700	8,000	4,800	5,310	8,240	14,600	8,790	3,570	2,900
11	12,500	5,660	7,000	4,500	7,900	4,700	5,100	12,500	14,900	8,210	3,410	2,660
12	12,200	5,640	7,000	6,000	7,700	5,000	5,080	15,900	14,900	7,870	3,410	2,980
13	12,000	5,590	7,000	8,000	7,500	5,500	5,130	18,400	14,500	7,480	3,260	2,540
14	11,800	5,560	7,000	8,500	7,200	6,500	4,980	23,200	17,000	7,260	3,110	2,480
15	11,800	5,670	7,000	8,500	7,000	8,500	5,230	22,200	17,300	7,140	3,050	2,420
16	11,700	5,870	7,000	8,400	6,600	11,000	5,630	17,800	14,800	8,050	3,180	2,360
17	11,600	6,100	7,000	8,000	6,300	15,000	5,490	15,400	12,800	8,370	3,180	5,380
18	11,600	5,770	7,000	7,600	6,000	20,000	5,420	13,700	11,600	8,050	3,090	5,010
19	11,400	5,530	6,600	7,300	5,600	23,000	5,180	12,000	11,400	7,780	2,740	4,580
20	11,200	5,530	6,400	6,800	5,200	23,000	5,310	10,200	11,700	7,450	2,520	5,010
21	11,200	5,500	5,900	6,400	4,800	21,000	5,390	9,200	13,100	6,890	2,840	5,210
22	11,000	5,440	6,500	6,000	4,700	17,000	5,600	8,380	14,500	6,380	3,700	5,040
23	11,200	5,380	7,000	5,800	4,500	14,000	5,520	7,760	15,600	5,990	3,700	4,870
24	11,000	5,370	7,500	5,700	4,300	11,000	5,290	7,500	17,100	6,950	4,630	4,870
25	11,000	5,850	8,000	5,500	4,500	9,000	5,030	8,490	19,600	5,890	5,510	4,700
26	11,000	5,810	7,500	5,100	4,500	8,500	5,390	14,700	21,900	5,610	5,460	4,510
27	10,800	5,700	6,800	4,800	4,700	8,000	6,480	13,700	19,000	5,940	4,990	4,390
28	10,800	5,500	6,000	4,500	4,800	7,800	6,140	10,700	17,000	5,940	4,580	4,440
29	10,600	5,500	5,000	4,400	------	7,500	6,090	9,240	15,300	5,710	4,180	4,440
30	10,400	5,300	4,500	4,300	------	10,000	5,980	12,900	13,600	6,760	3,840	4,610
31	10,200	------	4,000	4,200	------	14,000	------	19,000	------	6,220	3,480	------
TOTAL	371,100	193,850	207,700	179,400	167,900	299,200	174,130	340,600	527,000	268,550	119,900	110,140
MEAN	11,970	6,462	6,700	5,787	5,996	9,652	5,804	10,990	17,570	8,663	3,868	3,671
MAX	14,100	9,900	8,000	8,500	8,300	23,000	10,600	23,200	26,600	14,400	5,510	5,380
MIN	10,200	5,300	4,000	3,700	4,200	4,700	4,980	4,380	11,400	5,540	2,520	2,360
AC-FT	736,100	384,500	412,000	355,800	333,000	593,500	345,400	675,600	1,045M	532,700	237,800	218,500
(†)	3,630	4,950	5,120	3,960	0	0	10,340	68,770	69,240	80,110	63,220	50,380

CAL YR 1965 TOTAL 6,522,110 MEAN 17,870 MAX 86,500 MIN 4,000 AC-FT 12,940,000 † 296,900
WTR YR 1966 TOTAL 2,959,470 MEAN 8,108 MAX 26,600 MIN 2,360 AC-FT 5,870,000 † 375,700

† DIVERSIONS, IN ACRE-FEET, BY LOWER YELLOWSTONE CANAL, FURNISHED BY BUREAU OF RECLAMATION.
M EXPRESSED IN THOUSANDS.

Figure 4-1 - Streamflow Data from USGS Water Supply Paper (47)

Streamflow data can also be acquired from WATSTORE, the National Water Data Storage and Retrieval System. The WATSTORE system is a series of water related data banks and associated retrieval and processing programs maintained by the USGS. Acquisition of data with WATSTORE offers the following advantages: the entire period of record may be accessed; data contains the most recent revisions; data may be output in tables, on data cards or on magnetic tape; the system includes a series of statistical programs appropriate for low-flow analysis; and data retrieval procedures include the ability to search and retrieve data within a specified geographic region (defined by latitude-longitude coordinates).

The WATSTORE system can be utilized to produce a variety of data appropriate for water balance preparation and water supply analysis, including the following:

1. Mean daily and monthly flow data
2. Summaries of mean monthly and yearly flow data
3. Flow duration analysis
4. Low and high flow analysis
5. Log-Pearson Type III statistics and plots of low and high flow data
6. Reservoir storage and elevation data
7. Well level data

User manuals for the WATSTORE system (15) describe in detail the procedures and available options for streamflow analyses. Figure 4-2 is an example of a WATSTORE output showing average monthly and annual flows. A similar table is available for daily flow values.

Although the WATSTORE system can readily produce period of record data and flow analyses, these data should be used with caution as the historic record

STATION NUMBER 01463500 DELAWARE R AT TRENTON NJ STREAM SOURCE AGENCY USGS
LATITUDE 401318 LONGITUDE 0744642 DRAINAGE AREA 6780.00 DATUM 7.77 STATE 34 COUNTY 021

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976
MEAN VALUES

1976	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
TOTAL	548040	498320	324650	613000	778100	509900	402450	392620	224690	266920	248220	143990
MEAN	17680	16610	10470	19770	26830	16450	13420	12670	7490	8610	8007	4800
MAX	58200	34000	14300	99600	47300	23700	36000	19400	12800	18600	19100	8120
MIN	7580	9230	6180	7000	12000	12100	6380	8530	4540	4660	4500	3280

WTR YR 1976 TOTAL 4950900 MEAN 13530 MAX 99600 MIN 3280

1977	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
TOTAL	558590	324010	231770	116400	211000	1191200	785810	331380	142770	122110	115370	248330
MEAN	18020	10800	7476	3755	7536	38430	26190	10690	4759	3939	3722	8278
MAX	50700	21900	17400	4900	32200	108000	54800	18000	8070	7170	5340	39700
MIN	6420	5480	3950	2250	2200	21000	8370	4020	3400	2480	2520	2590

WTR YR 1977 TOTAL 4378740 MEAN 12000 MAX 108000 MIN 2200

Figure 4-2. Table of Monthly and Annual Flow Data Retrieved by WATSTORE (15)

may not be stationary. This means that during the period of data collection the stream gage may have been relocated, or the hydrologic character of the basin may have been altered by the construction of reservoirs, irrigation diversions or other water use facilities. The history of a region's water development is generally known by local purveyors and state water agencies.

Adjustments to streamflow data. Flow data from nonstationary gages may be adjusted to present conditions to provide a consistent data set of flow data. Changes due to the construction of reservoirs may be determined by the use of reservoir simulation models such as HEC-3 and HEC-5 (44, 45). The impact of changed consumptive use may be accounted for by subtracting the difference in consumptive use from the predevelopment portions of the historic record. Adjustments to account for changes in consumptive use, particularly agricultural use, should be made with care since consumptive use varies with climatic conditions.

Computer program HEC-4, Monthly Streamflow Simulation (42) can be used to extend short streamflow records or to fill in data for gages with discontinuous records. Data requirements consist of observed monthly streamflow data from a number of similar basins. The program reconstitutes missing data on the basis of concurrent flows recorded at the other locations.

Ungaged Streams. When streamflow data are unavailable a variety of procedures ranging from simple hand techniques to sophisticated computer analysis may be used to develop streamflow estimates. For example, flow data from a gage upstream of the desired data location can be adjusted to account for the difference in runoff between two locations. The flow data should be proportioned by drainage area ratio and adjustments should be made for any significant inflows, diversions or consumptive uses. In a similar manner, flow data from a

nearby gaged basin of similar size and hydrologic characteristics can be adjusted and transferred to provide flow estimates for an ungaged basin. Important hydrologic characteristics to consider include those factors which affect low flow, such as geology, land use, density of phreatophytes, and the relative abundance of lakes and marshes.

These and other methods of streamflow correlation including graphical and regression analysis are described in IHD, Volume 2, Hydrologic Data Management (2).

Continuous simulation models, such as the Stanford Watershed Model, have the capability to produce streamflow sequences at ungaged sites from precipitation data. However, studies with continuous simulation models require substantial amounts of climatic, hydrologic and physiographic data.

Surface storage

Surface water storage is an important consideration in water balances because storage facilities are often significant determinants of water balance boundaries, and agencies which operate the facilities are often sources of information concerning depletions, in-stream uses, and water demands.

The contribution of a water storage facility to a water supply system can be determined in several ways. Data for a water balance with a current or recent time frame (within the life of the facility) can be obtained directly from the operating agency or indirectly from USGS Water Supply Papers or from WATSTORE.

When data are not available hand computations or computer simulation models may be used to develop the required data. Data required to analyze the water supply potential of a surface storage facility include:

1. Hydrologic data. Sequential flow data representative of reservoir inflows during the water balance time frame (i.e., historic drought or other analysis period).

2. Climatic data. Evaporation and precipitation data, usually combined and expressed as net evaporation.

3. Reservoir characteristics. The physical characteristics necessary to model the storage and release features of a reservoir, particularly the relationship of reservoir elevation to storage, surface area, and outlet capacity.

4. Operating criteria. The operational policies governing the storage and release of water at a particular reservoir.

Mean monthly flow data are usually appropriate for reservoir water supply analyses and may be obtained from the previously cited sources. Net evaporation data for average and dry climatic conditions for about 130 locations throughout the United States are contained in the Corps of Engineers Engineer Manual 1110-2-1701, Hydropower (38). Maps of average annual net evaporation for most basins in the U. S. are also contained in Inter-Agency Regional Comprehensive Framework Study reports. The availability of observed evaporation and precipitation data are discussed later in this section. Reservoir characteristics and operational criteria should be obtained from the appropriate operating and design agencies.

Ground water (pumpage)

Ground water pumpage can be determined by the following procedures: 1) directly from well production data obtained from producers; 2) indirectly through the analysis of changes in ground water storage and estimates of

recharge; and 3) estimates through the application of water use factors, i.e., agriculture production may be estimated with acreage data, crop information and irrigation efficiency data.

Ground water storage

Procedures to analyze ground water storage are described in IHD, Volume 10, Principles of Ground Water Hydrology (8) and in ground water texts such as Ground Water Hydrology (36).

The change in ground water storage, an indicator of the long term availability of ground water, may be determined by:

$$\text{Change in storage} = A \times \Delta WSEL \times S$$

A = surface area of the aquifer, in acres

ΔWSEL = the average change in water surface elevations in the area during the specified time period, in ft

S = average storage coefficient for the area

Storage coefficient data should be obtained from local agencies or from USGS field offices. Information necessary to determine the change in water table elevations may also be obtained from local agencies or from water level data retrieved from the WATSTORE system. An example of water level data retrieved from WATSTORE is shown in Figure 4-3. The data includes mean daily water level (depth from a surface datum to the water surface) observations shown at five day intervals, mean monthly water levels, and the observed high and low levels and the mean level for the water year.

Imported water

Information to quantify the availability and use of imported water should be sought from local purveyors, state water development agencies and the Water and Power Resource Service (formerly U. S. Bureau of Reclamation).

STATION NUMBER 352649086131400 CF:F-92 NORMANDY, TENN (H-2) WELL SOURCE AGENCY USGS
LATITUDE 352649 LONGITUDE 0861314 WELL DEPTH 206.00 GEOLOGIC UNIT DATUM 940.00 STATE 47 COUNTY 031

WATER LEVEL, IN FEET BELOW LAND SURFACE DATUM, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
5	11.89	11.50	10.87	10.45	10.98	11.57	10.63	12.15	11.07	11.23	12.26	12.57
10	10.70	11.66	11.30	1C.82	11.49	11.52	11.34	12.21	11.47	11.08	12.38	12.71
15	11.21	10.66	11.60	10.87	11.67	11.17	11.66	11.47	11.81	11.60	12.52	12.87
20	10.08	11.16	11.04	11.18	10.84	11.27	11.85	10.99	11.97	11.88	12.60	12.97
25	10.91	11.44	11.37	11.46	10.85	11.12	11.96	11.45	12.12	12.03	12.68	13.06
EOM	11.28	11.42	10.85	10.96	11.20	10.51	12.10	11.73	11.79	12.11	12.71	12.87
MEAN	11.07	11.31	11.14	10.90	11.24	11.26	11.45	11.67	11.71	11.65	12.48	12.83

WTR YR 1976 MEAN 11.56 HIGH 10.08 OCT 20 LOW 13.07 SEP 26

Figure 4-3. Well water level data retrieved from WATSTORE (15)

Return flow

Return flow may be a significant source of streamflow, particularly in arid or high water use regions. Information concerning the magnitude of return flow and discharge location may be acquired directly from local sources such as irrigation districts, municipalities, industries and utilities. The level of detail from local data sources will vary from continuous flow measurements for many sanitary waste dischargers to no records for some agricultural dischargers. Return flow data for non-agricultural dischargers can also be obtained from the Environmental Protection Agency (EPA).

Under the provisions of the Federal Water Pollution Control Act the EPA has established the National Pollutant Discharge Elimination System (NPDES) to issue discharge permits and to monitor discharges from point sources to the nations surface and ground waters. NPDES permits require virtually all dischargers to report at regular intervals, the quantity, and point of discharge of their return flows. Most irrigation and storm water dischargers, however, are exempt from the NPDES permit requirements. NPDES permits require dischargers with return flows of greater than 0.25 MGD to report the average quantity and quality of their discharge to the EPA or state water pollution control agency on a monthly basis. NPDES reports are available from regional EPA and state water quality agencies.

Figure 4-4 is an example of an NPDES Discharge Monitoring Report. The report provides information on the average discharge (28.22 MGD) for the month, the location of the discharge point (latitude-longitude), and related water quality data.

A procedure to estimate agricultural return flows is discussed under agricultural use.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
DISCHARGE MONITORING REPORT

Form Approved
OMB NO. 158-R0073

ST	PERMIT NUMBER	DIS	SIC	LATITUDE	LONGITUDE
	NV 0020117	01		36°06'N	115°02'W

REPORTING PERIOD: FROM 78 10 01 (YEAR MO DAY) TO 78 10 31 (YEAR MO DAY)

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum (and/or minimum as appropriate) permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. (e.g., "3/7" is equivalent to 3 analyses performed every 7 days.) If continuous enter "CONT."
5. Specify sample type ("grab" or "__ hr. composite") as applicable. If frequency was continuous, enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER		QUANTITY MINIMUM	QUANTITY AVERAGE	QUANTITY MAXIMUM	UNITS	NO. EX	CONCENTRATION MINIMUM	CONCENTRATION AVERAGE	CONCENTRATION MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
FLOW	REPORTED	25.32	28.22	29.49								CONT.	
	PERMIT CONDITION		36										
INFLUENT BOD_5	REPORTED	21,328	40,010	73,292			101	170	298	mg/l		DAILY	COMP
	PERMIT CONDITION	--	--	--			--	--	--				
EFFLUENT BOD_5	REPORTED	4476	6303	7953			18.42	26.78	34.7	mg/l		DAILY	COMP
	PERMIT CONDITION		8000				--	30	--				
PER CENT REDUCTION	REPORTED		84.2				--	--	--			N/A	
	PERMIT CONDITION		85				--	--	--				
INFLUENT SUSPENDED SOLIDS	REPORTED	20,494	51,778	89,365			89	220	370	mg/l		DAILY	COMP
	PERMIT CONDITION		--				--	--	--				
EFFLUENT SUSPENDED SOLIDS	REPORTED	4161	5879	7142			17.5	24.98	30.4	mg/l		DAILY	COMP
	PERMIT CONDITION		8000				--	30	--				
PER CENT REDUCTION	REPORTED		88.7				--	--	--			N/A	
	PERMIT CONDITION		85				--	--	--				
SETTLEABLE SOLIDS	REPORTED						0.01	0.03	0.5	ml/l		DAILY	DISCRETE
	PERMIT CONDITION						--	0.1	0.2				

NAME OF PRINCIPAL EXECUTIVE OFFICER	TITLE OF THE OFFICER	DATE (YEAR MO DAY)
WREN-JARVIS, JAMES	DIST. SANITARY ENGINEER	79 01 11

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief such information is true, complete, and accurate.

J. Wren-Jarvis
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

Figure 4-4

Saline water

The best sources of information concerning the use of saline water are users of cooling water, principally industries and steam-electric utilities.

USE COMPONENTS

Agricultural use

Data required to determine the quantity of streamflow diverted for agricultural use should be obtained directly from the principal agricultural diverters or from other local sources such as irrigation districts, or local watermasters. In western states the state water rights boards and the Water and Power Resource Service are also sources of agricultural water use data. The Economics, Statistics, and Cooperative Service of the U. S. Department of Agriculture and state crop and livestock reporting services can provide annual estimates of applied irrigation water on a county basis.

When local data are unavailable or if a water balance is being conducted for a future period, diversions and return flows may be estimated by computing crop requirements using land use information, crop consumptive use data, and irrigation efficiency factors. The Soil Conservation Service (SCS) has compiled the necessary crop consumptive use data and efficiency factors to estimate monthly and annual irrigation diversions in Water Resource Council (WRC) subareas for normal and dry climatic conditions (48). Many states can provide similar data.

Figure 4-5 is an example of SCS crop water use data for normal precipitation conditions, for three WRC subareas (SA) in Wyoming. Data includes monthly and annual crop consumptive use, off-farm conveyance efficiencies, on-farm efficiencies, and incidential losses for three levels of water management. The procedure to estimate the irrigation diversions required to irrigate 1000 acres of wheat during the month of June in the Big Horn River Basin (WRC SA 1008) is shown in the following example.

STATE: 56 WYOMING

SCS WATER USE COEFFICIENTS AND EFFICIENCIES
FOR THE NATIONAL WATER ASSESSMENT (JUN 75)
(NORMAL YEAR OR 50 PERCENT PRECIPITATION)

ASA	SA	CROP	CROP CONSUMPTIVE IRRIGATION REQUIREMENT JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	CONVEYANCE EFF 1975	2000	HIGH	ON-FARM EFF 1975	2000	HIGH	INCID LOSS(%RF) 1975	2000	HIGH
		(WATER USE DATA ARE ACRE-FEET/ACRE ; EFFICIENCIES ARE EXPRESSED AS PERCENTAGES)																						
1004	1008	WHEAT	.00	.00	.00	.10	.30	.40	.30	.00	.00	.00	.00	.00	1.10	59	63	77	39	42	50	6	6	7
1004	1008	CORN GRAIN	.00	.00	.00	.00	.10	.20	.50	.40	.10	.00	.00	.00	1.30	59	63	77	39	42	50	6	6	7
1004	1008	CORN SILAGE	.00	.00	.00	.00	.00	.20	.50	.50	.00	.00	.00	.00	1.20	59	63	77	39	42	50	6	6	7
1004	1008	OATS	.00	.00	.00	.10	.30	.40	.30	.00	.00	.00	.00	.00	1.10	59	63	77	39	42	50	6	6	7
1004	1008	BARLEY	.00	.00	.00	.10	.30	.40	.30	.00	.00	.00	.00	.00	1.10	59	63	77	39	42	50	6	6	7
1004	1008	VEG (SHALLOW)	.00	.00	.00	.00	.00	.40	.60	.10	.00	.00	.00	.00	1.10	59	63	77	39	42	50	6	6	7
1004	1008	VEG (DEEP)	.00	.00	.00	.00	.00	.50	.60	.10	.00	.00	.00	.00	1.20	59	63	77	39	42	50	6	6	7
1004	1008	HAY (ALFALFA)	.00	.00	.00	.00	.20	.40	.60	.50	.30	.00	.00	.00	2.00	59	63	77	39	42	50	6	6	7
1004	1008	HAY(CLVR-GRASS)	.00	.00	.00	.10	.20	.40	.50	.40	.20	.10	.00	.00	1.90	59	63	77	39	42	50	6	6	7
1004	1008	HAY (HAYSEED)	.00	.00	.00	.10	.20	.40	.50	.40	.20	.10	.00	.00	1.90	59	63	77	39	42	50	6	6	7
1004	1008	HAY (OTHER)	.00	.00	.00	.10	.20	.40	.40	.40	.20	.10	.00	.00	1.80	59	63	77	39	42	50	6	6	7
1004	1008	SUGAR BEETS	.00	.00	.00	.00	.10	.30	.60	.50	.30	.00	.00	.00	1.80	59	63	77	39	42	50	6	6	7
1004	1008	IRISH POTATOES	.00	.00	.00	.00	.10	.40	.60	.50	.00	.00	.00	.00	1.60	59	63	77	39	42	50	6	6	7
1004	1008	DRY BEANS	.00	.00	.00	.00	.00	.20	.50	.30	.00	.00	.00	.00	1.00	59	63	77	39	42	50	6	6	7
1004	1008	CROP PASTURE	.00	.00	.00	.10	.20	.40	.50	.40	.20	.10	.00	.00	1.90	59	63	77	39	42	50	6	6	7
1004	1008	OTHER PASTURE	.00	.00	.00	.10	.20	.30	.50	.40	.20	.10	.00	.00	1.80	59	63	77	39	42	50	6	6	7
1004	1008	OTHER CROPS	.00	.00	.00	.10	.20	.30	.50	.40	.20	.10	.00	.00	1.80	59	63	77	39	42	50	6	6	7
1004	1009	WHEAT	.00	.00	.00	.00	.10	.30	.50	.20	.00	.00	.00	.00	1.10	69	71	78	37	40	48	5	6	8
1004	1009	CORN GRAIN	.00	.00	.00	.00	.00	.10	.40	.40	.10	.00	.00	.00	1.00	69	71	78	37	40	48	5	6	8
1004	1009	CORN SILAGE	.00	.00	.00	.00	.00	.10	.40	.40	.00	.00	.00	.00	.90	69	71	78	37	40	48	5	6	8
1004	1009	OATS	.00	.00	.00	.00	.10	.30	.50	.20	.00	.00	.00	.00	1.10	69	71	78	37	40	48	5	6	8
1004	1009	BARLEY	.00	.00	.00	.00	.10	.30	.50	.20	.00	.00	.00	.00	1.10	69	71	78	37	40	48	5	6	8
1004	1009	VEG (DEEP)	.00	.00	.00	.00	.00	.10	.40	.40	.00	.00	.00	.00	.90	69	71	78	37	40	48	5	6	8
1004	1009	HAY (ALFALFA)	.00	.00	.00	.00	.20	.30	.50	.40	.20	.00	.00	.00	1.60	69	71	78	37	40	48	5	6	8
1004	1009	HAY(CLVR-GRASS)	.00	.00	.00	.00	.10	.30	.50	.40	.20	.00	.00	.00	1.50	69	71	78	37	40	48	5	6	8
1004	1009	HAY (HAYSEED)	.00	.00	.00	.00	.10	.30	.50	.40	.20	.00	.00	.00	1.50	69	71	78	37	40	48	5	6	8
1004	1009	HAY (OTHER)	.00	.00	.00	.00	.10	.20	.50	.40	.20	.00	.00	.00	1.40	69	71	78	37	40	48	5	6	8
1004	1009	SUGAR BEETS	.00	.00	.00	.00	.00	.20	.50	.50	.20	.00	.00	.00	1.40	69	71	78	37	40	48	5	6	8
1004	1009	IRISH POTATOES	.00	.00	.00	.00	.00	.10	.50	.50	.10	.00	.00	.00	1.20	69	71	78	37	40	48	5	6	8
1004	1009	CROP PASTURE	.00	.00	.00	.00	.10	.30	.50	.40	.20	.00	.00	.00	1.50	69	71	78	37	40	48	5	6	8
1004	1009	OTHER PASTURE	.00	.00	.00	.00	.10	.20	.50	.40	.20	.00	.00	.00	1.40	69	71	78	37	40	48	5	6	8
1004	1009	OTHER CROPS	.00	.00	.00	.00	.00	.20	.50	.50	.20	.00	.00	.00	1.40	69	71	78	37	40	48	5	6	8
1005	1012	WHEAT	.00	.00	.00	.00	.10	.30	.40	.10	.00	.00	.00	.00	.90	88	90	90	30	35	45	10	10	10
1005	1012	CORN GRAIN	.00	.00	.00	.00	.00	.10	.40	.40	.10	.00	.00	.00	1.00	88	90	90	30	35	45	10	10	10
1005	1012	CORN SILAGE	.00	.00	.00	.00	.00	.10	.40	.40	.00	.00	.00	.00	.90	88	90	90	30	35	45	10	10	10
1005	1012	OATS	.00	.00	.00	.00	.10	.30	.40	.10	.00	.00	.00	.00	.90	88	90	90	30	35	45	10	10	10
1005	1012	BARLEY	.00	.00	.00	.00	.10	.30	.40	.10	.00	.00	.00	.00	.90	88	90	90	30	35	45	10	10	10
1005	1012	HAY (ALFALFA)	.00	.00	.00	.00	.10	.30	.50	.50	.20	.00	.00	.00	1.60	88	90	90	30	35	45	10	10	10
1005	1012	HAY(CLVR-GRASS)	.00	.00	.00	.00	.10	.20	.50	.40	.20	.10	.00	.00	1.50	88	90	90	30	35	45	10	10	10
1005	1012	HAY (HAYSEED)	.00	.00	.00	.00	.10	.20	.50	.40	.20	.10	.00	.00	1.50	88	90	90	30	35	45	10	10	10
1005	1012	HAY (OTHER)	.00	.00	.00	.00	.10	.20	.40	.40	.20	.10	.00	.00	1.40	88	90	90	30	35	45	10	10	10

Figure 4-5. SCS water use coefficients (48)

Example 1: Estimation of Irrigation Requirements

Data for SA 1008 (from Figure 4-5, Top Row)

- June Crop Consumptive Irrigation Requirement (CIR) = .4 ac-ft/ac
- Conveyance Efficiency (CE), 1975 Level = 59%
- On-farm Efficiency (OFE), 1975 Level = 39%
- Incidential Loss (INCID), 1975 Level = 6%

Computations

Irrigation system efficiency (SE) = CE x OFE = .59 x .39 = .23

Gross Diversion Requirement (GDR) = Area (acres) x CIR/SE

GDR = 1000 acres x .4 ac-ft/ac/.23

GDR = 1740 ac-ft

Return Flow = GDR - Crop consumptive use - incidential loss

Crop consumptive use = 1000 acres x .4 ac-ft/ac = 400 ac-ft

Incidential loss = GDR x INCID = 1740 x .06 = 104 ac-ft

Return Flow = 1740 ac-ft - 400 ac-ft - 104 ac-ft = 1236 ac-ft

Municipal use

Municipal water use should be determined from local purveyors or from the analysis of their water meter or pump data whenever possible. If local data are unavailable, or if a water balance is to be computed for a future time period, municipal use may be estimated by computing the product of per capita water use factors and estimated population data. Water use factors are available from 1) purveyors within the region who serve communities of approximately the same size with similar economic and social characteristics; and 2) data from national surveys conducted periodically by the American Water Works Association (Table 1). In addition, state agencies often maintain records of municipal water use and water use factors within their geographic regions.

It is important that user data be collected and forecast by sector and season. Common use sectors under the municipal category are: residential and commercial (54). Residential may be further classified as indoor and outdoor and commercial use by type of service e.g. retail trade, offices, hospitals etc.

TABLE 1

MUNICIPAL WATER PRODUCTION BY GEOGRAPHIC REGIONS (32)

Region	Production (gpcd)				
	1950 mean	1955 mean	1960 mean	1965 mean	1970 mean
New England	111	123	108	120	153
Middle Atlantic	145	139	118	116	140
Northeast Central	132	130	116	152	160
Northwest Central	127	127	124	127	138
Atlantic Coast	---	---	---	134	156
Southeast Central	---	---	---	117	134
Southwest Central	---	---	---	138	157
Mountain	226	220	205	201	199
Pacific Coast	189	193	202	200	211
United States	138	137	131	148	167

Population data may be obtained from local or state governmental agencies and from the U. S. Census Bureau. Population projections may be available from state agencies. The U. S. Departments of Commerce and Agriculture have prepared projections of population and economic growth to the year 2020. These data are contained in 1972 OBERS Projection Series E Population published by the Water Resources Council (49).

Industrial Use

The majority of industrial water users in the United States (290,000 out of 312,000 industrial plants, according to the U. S. Department of Commerce) rely exclusively on municipal systems for water supply and waste discharge. Most water required for industrial use, however, about 88% of the total, is produced directly by industrial self-suppliers. Industries which self-supply are generally large manufacturing plants which are situated adjacent to lakes or rivers. Data for the analysis of industrial water use should be obtained directly from the major manufacturing plants whenever possible.

The U. S. Department of Commerce and the Census Bureau have compiled water use data from industrial plants that account for virtually all of the water used for industrial purposes in the United States. These data have been incorporated with OBERS regional economic information and water consumption and recirculation coefficients to provide a data base for the Department of Commerce Industrial Water Use Forecasting Model. The model is capable of forecasting industrial water use to the year 2000.

Water use data for a specific plant, however, cannot be retrieved from the data base because of the Census Bureau's prohibition regarding release of individual company data. This limitation would not be significant in an industrial region because the data is considered to lose its confidential nature when it is aggregated. The minimum permissible level of aggregation is three plants, with no single plant accounting for more than half of the total water use. Figure 4-6 is an example of data retrieved by the Department of Commerce Industrial Water Use Forecasting Model. This example shows the principal manufacturing use of water in WRC region 0900 (the Souris-Red-

DEPARTMENT OF COMMERCE FORECASTS OF MANUFACTURING WATER USE -- 1975, 1985, 2000

REGION 0900 , SIC 20 (FOOD AND KINDRED PRODUCTS)

	1975-MGY	1975MGCD	1975MGOD	1985-MGY	1985MGCD	1985MGOD	2000-MGY	2000MGCD	2000MGOD
GROSS WATER USE	8,730	24	35	10,739	29	43	14,107	39	56
INTAKE, TOTAL	5,527	15	22	3,485	10	14	2,710	7	11
INTAKE, PUBLIC SYSTEMS	735	2	3						
INTAKE, SELF SUPPLIED	4,716	13	19						
INTAKE, BRACKISH	76								
CONSUMPTION	1,504	4	6	1,727	5	7	2,027	6	8
DISCHARGE, TOTAL	4,023	11	16	1,758	5	7	683	2	3
DISCHARGE, PUBLIC SEWERS	1,012	3	4						
DISCHARGE, SURFACE WATERS	3,012	8	12						
DISCHARGE, OTHER									
RECIRCULATION RATE	1.594			3.184			5.569		
CONSUMPTION RATE	0.172			0.161			0.144		

REGION 0900 , SIC 26 (PAPER, PULP, AND BOARD)

	1975-MGY	1975MGCD	1975MGOD	1985-MGY	1985MGCD	1985MGOD	2000-MGY	2000MGCD	2000MGOD
GROSS WATER USE	50,429	138	153	67,265	184	204	91,111	250	276
INTAKE, TOTAL	31,240	86	95	11,882	33	36	7,787	21	24
INTAKE, PUBLIC SYSTEMS	26								
INTAKE, SELF SUPPLIED	31,215	86	95						
INTAKE, BRACKISH									
CONSUMPTION	3,429	9	10	4,574	13	14	6,196	17	19
DISCHARGE, TOTAL	27,811	76	84	7,308	20	22	1,591	4	5
DISCHARGE, PUBLIC SEWERS	24								
DISCHARGE, SURFACE WATERS	26,676	73	81						
DISCHARGE, OTHER	1,111	3	3						
RECIRCULATION RATE	1.615			5.675			11.765		
CONSUMPTION RATE	0.068			0.068			0.068		

REGION 0900 , SIC XX (ALL OTHER MANUFACTURING)

	1975-MGY	1975MGCD	1975MGOD	1985-MGY	1985MGCD	1985MGOD	2000-MGY	2000MGCD	2000MGOD
GROSS WATER USE	466	1	2	739	2	3	1,263	3	5
INTAKE, TOTAL	301	1	1	364	1	1	489	1	2
INTAKE, PUBLIC SYSTEMS	80								
INTAKE, SELF SUPPLIED	79								
INTAKE, BRACKISH	141		1						
CONSUMPTION	98			155		1	264	1	1
DISCHARGE, TOTAL	203	1	1	209	1	1	225	1	1
DISCHARGE, PUBLIC SEWERS	62								
DISCHARGE, SURFACE WATERS	141		1						
DISCHARGE, OTHER									
RECIRCULATION RATE	1.554			2.030			2.582		
CONSUMPTION RATE	0.210			0.210			0.209		

Figure 4-6. Water Use Forecast Prepared by the Department of Commerce Industrial Water Use Forecasting Model

Rainy drainages) for 1975, 1985, and 2000. Data includes use data in millions of gallons per year (MGY), millions of gallons per calendar day (MGCD), and millions of gallons per operational day (MDOD) for various supply and disposal systems.

Nuclear or fossil fueled steam electric plant cooling is the dominant use of water in eastern United States. Although withdrawal for steam-electric use amounts to about 25% of the nation's total fresh water use, only about 2% of the amount withdrawn is used consumptively; the remainder is returned to its source.

Local utilities are the best source of data concerning withdrawal, consumptive use, and the location of intake and discharge points. Steam-electric water use data is also available from the Federal Energy Regulatory Commission (FERC). The commission requires all steam-electric plants 23MW or larger, to report air and water quality control data annually. The required data includes average annual rates of withdrawal, return flow, and consumption, as well as temperature and receiving water data. An example of the water use portion of a completed report (FPC Form 67, Part II) is shown in Figure 4-7 on the following page. These data are available from the five FERC regional offices and from some state water quality agencies.

Water Rights

Water rights (primarily a concern in western United States) are normally under the jurisdiction of state water rights boards. The Bureau of Indian Affairs should be contacted for information concerning Indian water rights.

In-Stream Flow

In-stream flow refers to the amount of water flowing in a natural stream required to maintain acceptable conditions for various in-stream uses,

STEAM-ELECTRIC PLANT AIR AND WATER QUALITY CONTROL DATA
PART II - WATER QUALITY CONTROL DATA
(Applicable to Nuclear and Fossil Fueled Steam-Electric Plants)

COMPANY NAME			REPORT FOR YEAR ENDED
PACIFIC POWER & LIGHT COMPANY			DECEMBER 31, 19 74
PLANT NAME			COMPANY - PLANT CODE
DAVE JOHNSTON			370500 1200
PLANT CAPACITY - MW	STATE	COUNTY	POST OFFICE AND ZIP CODE
750.3	WYOMING	CONVERSE	GLENROCK 82637

SCHEDULE A - OPERATIONAL DATA

Section 1 - Average Annual Cooling Water Use of Plant - CFS

LINE NO.	(a)	(b)	CHECK FOR FOOTNOTE * (c)
01	AVERAGE RATE OF WITHDRAWAL FROM WATER BODY DURING YEAR	292.9	
02	AVERAGE RATE OF DISCHARGE TO WATER BODY DURING YEAR	281.2	X
03	AVERAGE RATE OF CONSUMPTION DURING YEAR	9.1	X

Section 2 - Maximum Water Temperatures and Average Stream Flows During Months of Winter and Summer System Peak Power Loads

LINE NO.	WINTER PEAK LOAD MONTH December **			SUMMER PEAK LOAD MONTH July **			CHECK FOR FOOTNOTE * (g)
	MAXIMUM TEMPERATURE °F		MONTHLY AVERAGE FLOW IN RECEIVING WATER BODY, CFS	MAXIMUM TEMPERATURE °F		MONTHLY AVERAGE FLOW IN RECEIVING WATER BODY, CFS	
	AT DIVERSION (a)	AT OUTFALL (b)	(c)	AT DIVERSION (d)	AT OUTFALL (e)	(f)	
04	39	90	881.3	71	118	3511.4	

Section 3 - Amount of Chemicals used During the Year

LINE NO.	(a)	PHOSPHATE LBS. (b)	CAUSTIC SODA LBS. (c)	HYDRAZINE GALS. (d)	LIME LBS. (e)	ALUM. LBS. (f)	CHLORINE LBS. (g)	OTHER (h)	CHECK FOR FOOTNOTE * (i)
05	COOLING WATER	56,510	None	None	None	None	34,000	Yes	X
06	BOILER WATER MAKEUP	1,336.5	813.5	825	None	110,000	None	Yes	X

SCHEDULE B - OPERATION AND MAINTENANCE EXPENSES, $1,000

Section 1 - Cooling Water Operation at Plant

LINE NO.	(a)	(b)	CHECK FOR FOOTNOTE * (c)
07	ANNUAL OPERATION AND MAINTENANCE EXPENSES	31 Est.	
08	ANNUAL COST OF CHEMICAL ADDITIVES	13 Est.	

Section 2 - Boiler Water Makeup and Boiler Blowdown Treatment

LINE NO.	(a)	(b)	CHECK FOR FOOTNOTE * (c)
09	ANNUAL OPERATION AND MAINTENANCE EXPENSES	97 Est.	
10	ANNUAL COST OF CHEMICAL ADDITIVES	13 Est.	

* All footnotes should be shown on page 20.
** Specify month.

Figure 4-7. Annual Water Use Data for a Steam-Electric Plant

FPC Form 67
Rev (6-70)

including fish and wildlife, navigation, hydroelectric power generation, water quality, salinity repulsion, recreation, and downstream water rights.

Information concerning in-stream flow use are available from the agencies shown in Table 2.

TABLE 2

SOURCES OF IN-STREAM FLOW DATA

Fish & Wildlife	U. S. Department of Interior Fish & Wildlife Service Office of Biological Service
	State Fish and Game Agencies
Navigation	U. S. Army Corps of Engineers
Hydroelectric Power	Department of Energy Office of Electric Power Regulation Corps of Engineers Federal Energy Regulatory Commission Electric Utilities
Water Quality, Salinity Repulsion	State Water Quality Agencies Inter-state Compact Commissions
Recreation	State Recreation Agencies

DEPLETIONS

Evaporation

Evaporation data are available from the following general sources:

1. Evaporation Maps for the United States (19). This publication consists of a series of national maps which show average annual gross lake evaporation, average May through October evaporation (% of annual) and Class A pan coefficients. They were developed from data collected at about 300 locations for the period from 1946 to 1955. This publication does not provide monthly evaporation values or data for dry climatic conditions.

2. Comprehensive Framework Studies. The Comprehensive Framework Studies are a series of planning reports prepared for most hydrologic regions of the country by federal inter-agency committees. These reports contain generalized evaporation data in the form of maps which show average annual gross and net lake evaporation and the monthly distribution of evaporation at selected locations. These publications do not provide data for dry climatic conditions.

3. EM 1110-2-1701, Hydropower (38). This manual contains average annual net evaporation data for 152 locations for five yearly periods. It also provides critical (drought) year corrections.

Net evaporation during drought periods can be several times greater than the average annual net evaporation indicated by the referenced map data. For this reason, when evaporation is expected to be a significant component of a drought period water balance, historic evaporation data should be acquired from the National Weather Service (NWS). The NWS published yearly summaries of weather data by state, in their report series entitled "Climatological Data, Annual Summary, state, year." These reports provide monthly evaporation data for the Class A Climatological stations within the state. An example is shown in Figure 4-8.

Table 4

TOTAL EVAPORATION AND WIND MOVEMENT

CALIFORNIA 1976

Station		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
• • • NORTH COAST DRAINAGE 01														
DUTTONS LANDING	EVAP	1.77B	2.07B	4.22B	5.62	8.99	10.76	8.97	6.42	5.27	4.08	2.35	2.00B	62.52
	WIND	4768	1616	2067	2557	3186	3140	3500	2767	1885	1189	798	7558	23936
	MAX	55.4	57.0	63.0	67.8	76.9	80.8	80.8	78.4	73.8	71.1	63.1	52.4	68.4
	MIN	36.2	41.6	40.5	43.0	49.1	52.9	54.8	55.8	54.4	50.8	48.0	37.9	47.1
TRINITY RIVER HATCH	EVAP	.73B	-	3.32B	4.46	8.79	9.46	10.17	6.66	6.53	3.47	1.12B	-	-
	WIND	635	842	1119	1226	1254	1067	941	835	773	473	446	520	10131
TULELAKE	EVAP	-	-	-	-	9.63	8.60B	8.66	6.32	7.76	-	-	-	-
WARM SPRINGS DAM	EVAP	1.53B	1.88B	3.86B	5.24	9.41B	10.88	10.12	7.58	6.64	5.41B	2.58	1.28	66.41
	WIND	1250	1291	1588	1433	21208	2240	1831	1590	1415	13908	1086	12718	18505
	MAX	-	-	68.3	73.0	-	88.8	-	-	-	-	-	-	-
	MIN	-	-	42.6	47.0	-	56.8	-	-	-	-	-	-	-
WILLOW CREEK 1 NW	EVAP	.73B	-	1.93B	2.59	6.01	7.38B	8.25	5.92B	4.21	2.33B	-	-	-
	WIND	888	194B	287B	443	550	619	612	510	372	264B	113	-	-
	MAX	-	-	62.7	68.5	83.0	86.4	92.3	84.2	84.7	76.0	-	-	-
	MIN	-	-	41.7	43.5	50.0	53.3	58.9	58.3	56.3	47.5	-	-	-

Figure 4-8. Class A pan evaporation data from "Climatological Data, Annual Summary, California, 1976"

Data includes monthly and annual Class A pan evaporation (EVAP) in inches. Net evaporation may be computed from Class A pan evaporation data by the procedure shown below:

Net Evaporation (inches) = EVAP x C + PRECIP

where:

EVAP = Class A pan evaporation in inches

C = Average annual Class A pan coefficients (usually taken to be 0.7)

PRECIP = The amount of precipitation occurring during the period

Evapotranspiration

Evapotranspiration, particularly by phreatophytes, may be a significant component of a water balance. Plants such as saltcedar and willow, that send their roots to the ground water table are heavy water users. Water use by phreatophytes, particularly in the western states, is a significant, but often unknown component.

The USGS has been the principal investigative agency to study water use by phreatophytes (7,30,31,51). Their studies show that evapotranspiration from phreatophytes is dependent upon: plant characteristics such as species, density, maturity; ground water characteristics such as water quality and depth to ground water; and climatic conditions such as wind and temperature.

Standard methods to estimate evapotranspiration are described in the Handbook of Applied Hydrology (6) and in USGS Water Supply Papers. Local offices of the USGS, WPRS, and SCS may be able to provide estimates of evapotranspiration in many areas.

Seepage

Information to estimate the loss of streamflow by seepage may be available from local offices of the USGS, SCS, WPRS, and state water agencies, or it can be computed from streamflow measurements. The determination of seepage data from field data requires measurements of inflow and outflow for a representative reach of stream during steady flow conditions. The difference between the observed inflow and outflow is the seepage for the reach (usually expressed as cfs/mile). In a region with a high water table the observed outflow may be greater than the inflow. In this case seepage is negative, that is, the stream is gaining flow from ground water. Since seepage is related to the depth to ground water, seepage can be expected to increase when water tables lower (i.e., during protracted droughts).

SECTION 5

PRESENTATION OF DATA

One important aspect of a water balance study is the summarization and presentation of information in a clear and concise manner. A variety of presentations ranging from aerial photographs to tables and charts can be used to aid the reader/reviewer in the interpretation of water supply/use data.

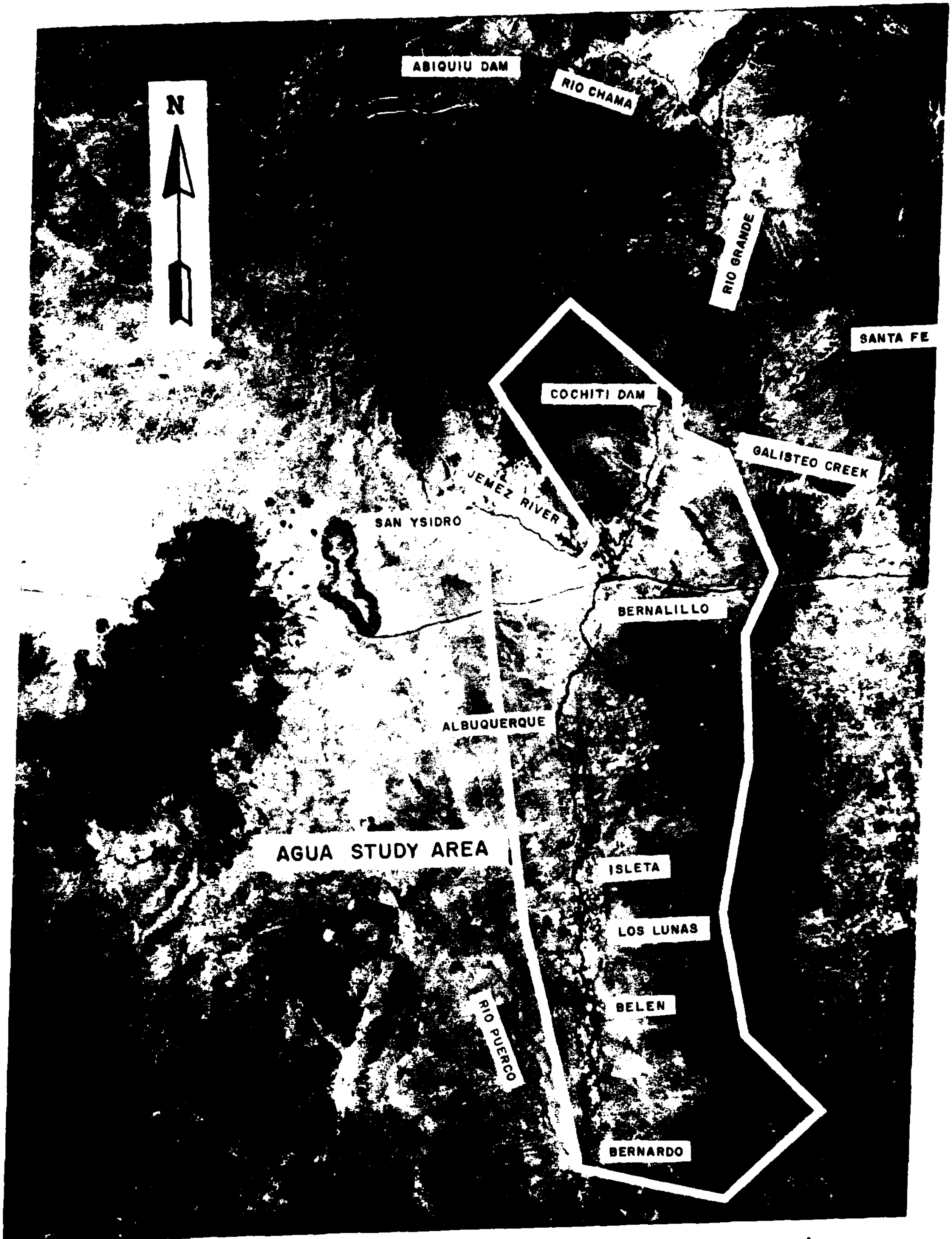
STUDY AREA BOUNDARIES

Aerial photographs and maps are particularly useful in showing the location of study boundaries, their spatial relationship to data sources, such as stream and precipitation gage sites, and the areas of water supply and use. Figure 5-1 is an example of an aerial photograph used to show the location and extent of study area boundaries for the AGUA study (39). This figure was developed from a LANDSAT photograph of the Albuquerque, New Mexico area. It clearly shows the boundaries of the study area, and their relationship to important areas of water use: the City of Albuquerque and the agricultural areas adjacent to the Rio Grande.

Because the study area covered 2800 square miles, a LANDSAT photograph was necessary. Where the geographic area is smaller, for example, a city, water district, or supply reservoir, lower altitude photographs should be used. Figure 5-2 illustrates the use of aerial photography to show boundaries for a small urban watershed (5.6 sq. mi.).

WATER BALANCE COMPONENTS

Component data may be presented in tables, charts, and graphs. Although tables are an effective method of summarizing component data for report presentations, other types of presentations, particularly charts and graphs,



ALBUQUERQUE GREATER URBAN AREA (AGUA)
STUDY AREA

NASA LANDSAT PHOTO MOSAIC (BAND 7) 12 MAY 74

Figure 5-1. Study Boundaries of the Albuquerque Greater Urban Area (AGUA)(39)

Figure 5-2. Study Boundaries for Small Urban Watershed

may be more applicable for public presentations. They are advantageous because they allow the viewer to easily make visual comparisons between components and to readily observe trends. Figure 5-3 is an example of a bar chart which shows the use of surface and ground water by agriculture and industry during a twenty-five year span. The obvious trends of increased ground water use by agriculture and increased surface water use by industry would not have been apparent in a tabular format.

Figure 5-4 illustrates the use of a graph and pie charts to present water use data. As may be seen from this example, pie charts allow the viewer to make a quick visual comparison between components, and graphs allow the viewer to judge visually the validity of extrapolating projected data.

RELATIONSHIPS BETWEEN COMPONENTS

A variety of graphics can be utilized to illustrate and quantify the relationship between components of a water balance study. Schematics of the local hydrologic system are often an appropriate means to illustrate the linkages between components of complex systems. Figures 5-5 and 5-6 are examples of two types of schematic representations of complex hydrologic systems. Figure 5-5 is a pictorial representation of a hydrologic system viewed at a typical cross section within a water balance study area. Figure 5-6 is a schematic diagram illustrating in detail the interrelationships between surface water components of Figure 5-5. A similar figure was prepared for the ground water system. Figure 5-7 is a flow diagram which symbolically illustrates the hydrologic system of Long Island, New York. Although both pictorial and flow diagrams can be utilized, pictorial representations are preferred because they are generally better understood by the lay public.

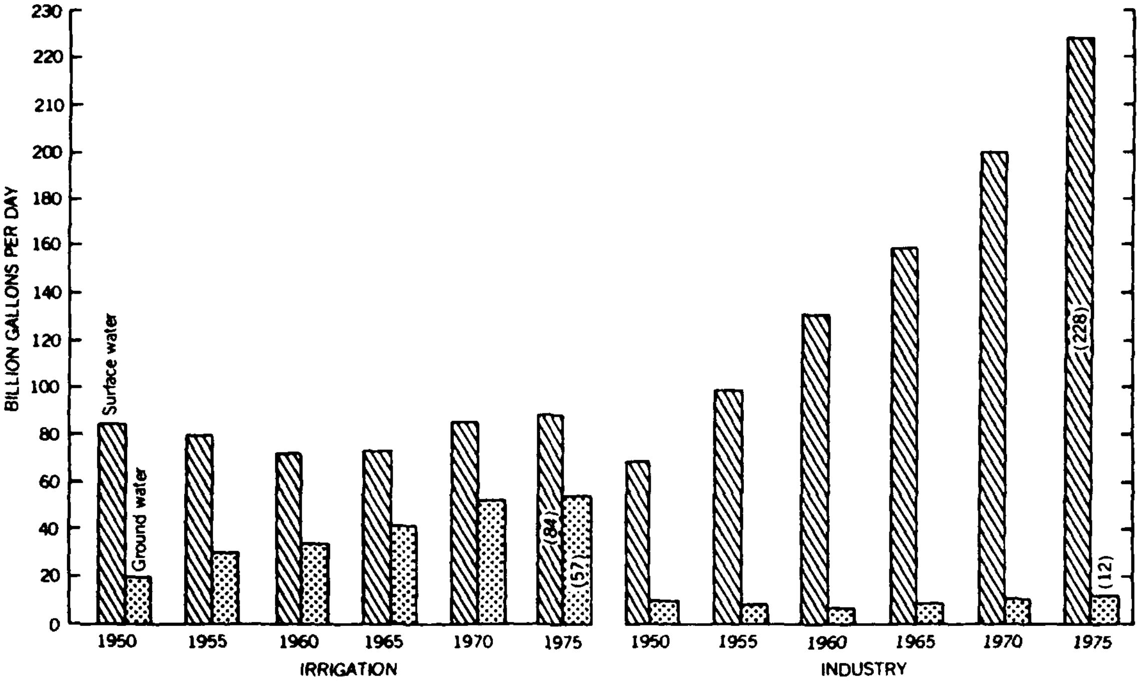


Figure 5-3. Bar graphs showing the use of water for irrigation and industry in the United States, 1950-1975. (23)

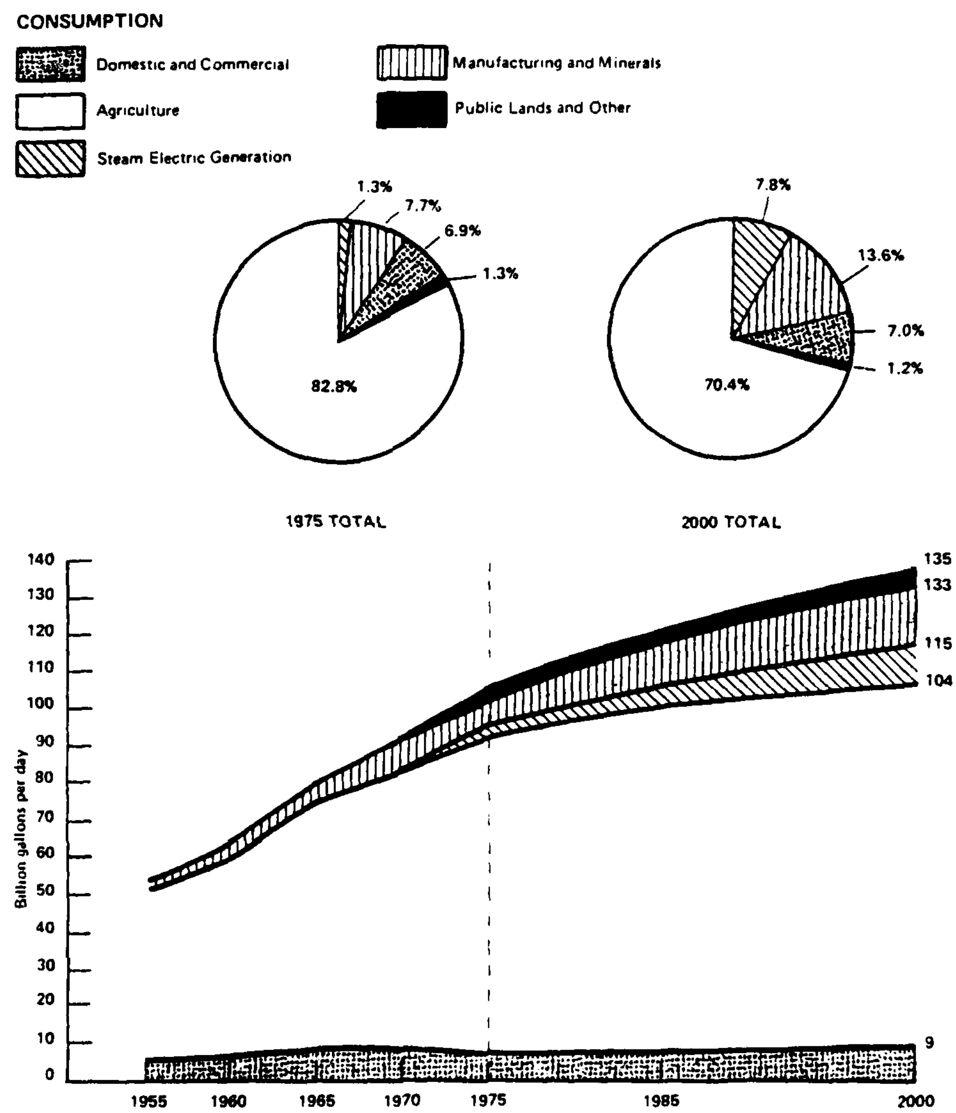


Figure 5-4. Pie charts and graph showing components of consumptive use of fresh water in the United States. (50)

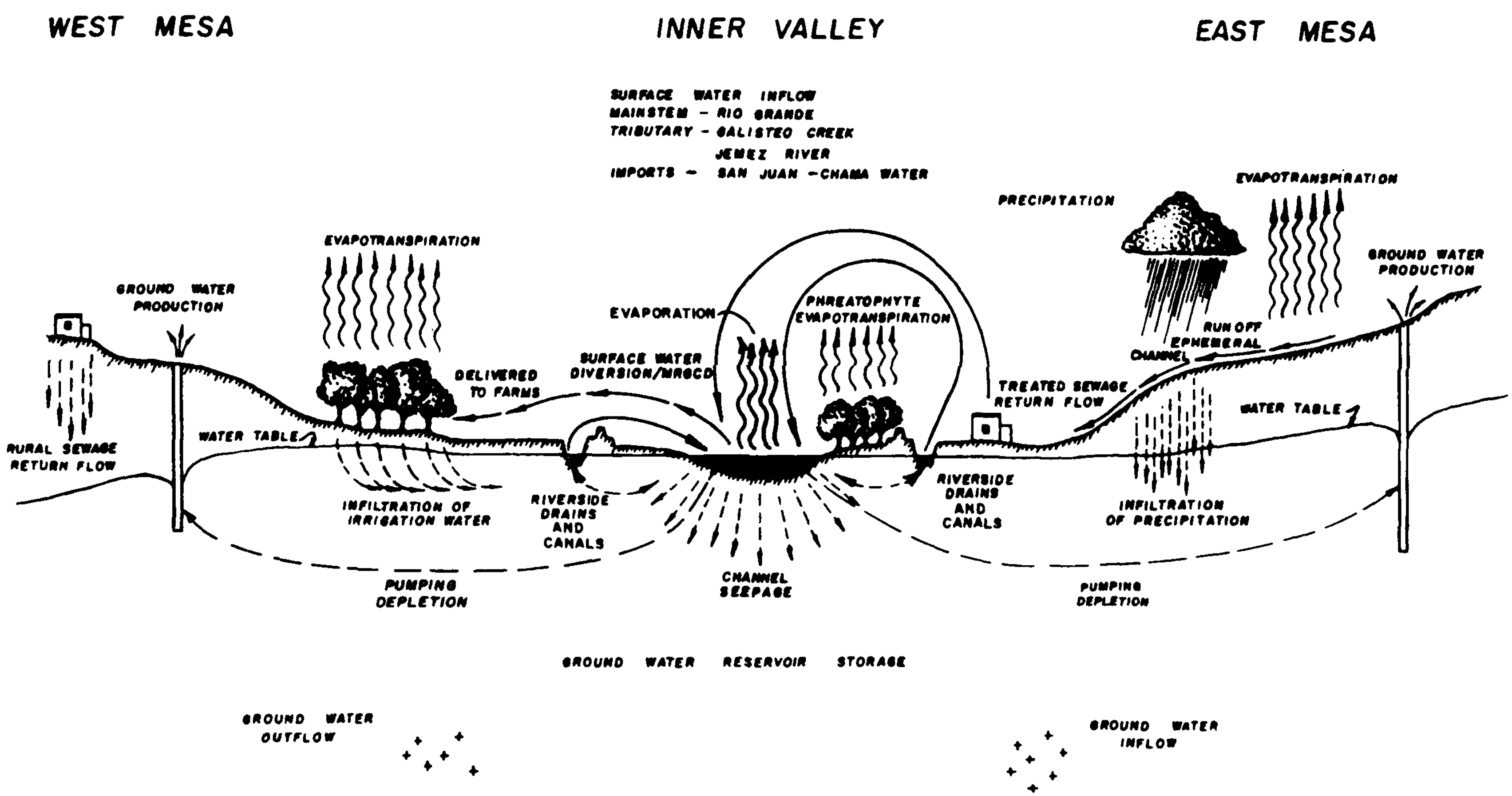


Figure 5-5. Components of the hydrologic system, Albuquerque, New Mexico (39)

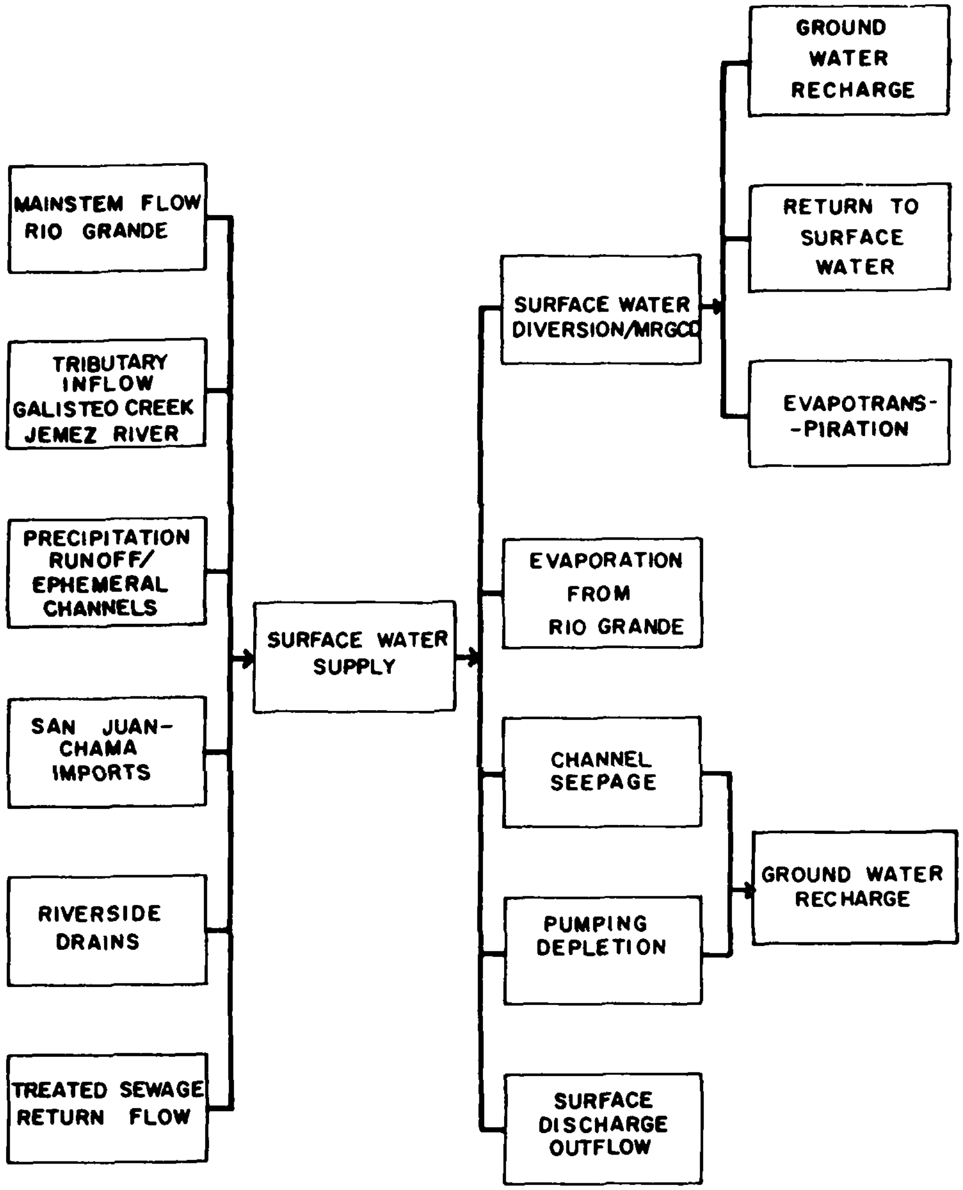


Figure 5-6. Schematic Diagram Illustrating the Interrelationships between Surface Water Components (39)

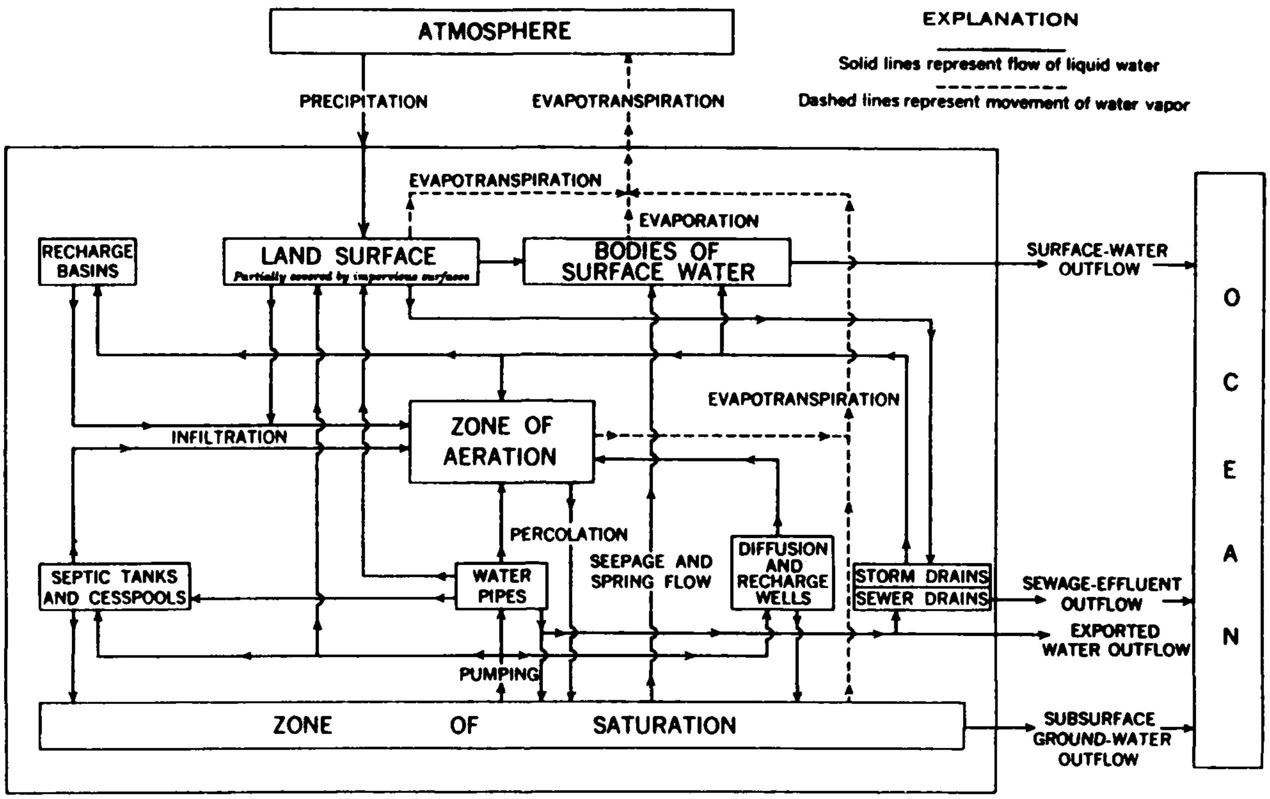


Figure 5-7. Schematic diagram of the hydrologic system of Long Island, NY (11)

Another type of presentation which is useful to illustrate water balance components is a "scaled" schematic diagram, which can show the magnitude of the individual components as well as linkages between components. The magnitude of the various components is stated by the scaled width of an arrow or flow path. Two examples of this type of presentation are shown in Figures 5-8 and 5-9. Figure 5-8 shows the water balance components of a municipal water delivery and disposal system. The width of the various components is indicative of their rate of flow through the system in the direction of the arrow heads. Figure 5-9 is a representation of agriculture water use components in the United States in 1975. The relative magnitude of the flow paths indicates the proportional distribution of flows.

Maps and aerial photographs should be used to present component data which have important spatial qualities. Figure 5-10 is an example of a map used to show the location of water supply system components. The important geographic aspects of water supply systems, particularly sites of interconnections, are best shown with this type of presentation.

WATER BALANCE RESULTS

The final results of a water balance analysis can also be presented in a variety of ways: tables, charts, graphs, and maps. A tabular format is generally used for report purposes. Tables are advantageous for several reasons: 1) they are capable of conveying detailed information in a relatively straightforward manner; 2) the reader/reviewer can see in one place the results of previous computations and tabulations; 3) data are summarized and thus can be readily extracted for other uses; and 4) footnotes and other explanatory information can be used to clarify the data. Figure 5-11 is a tabular

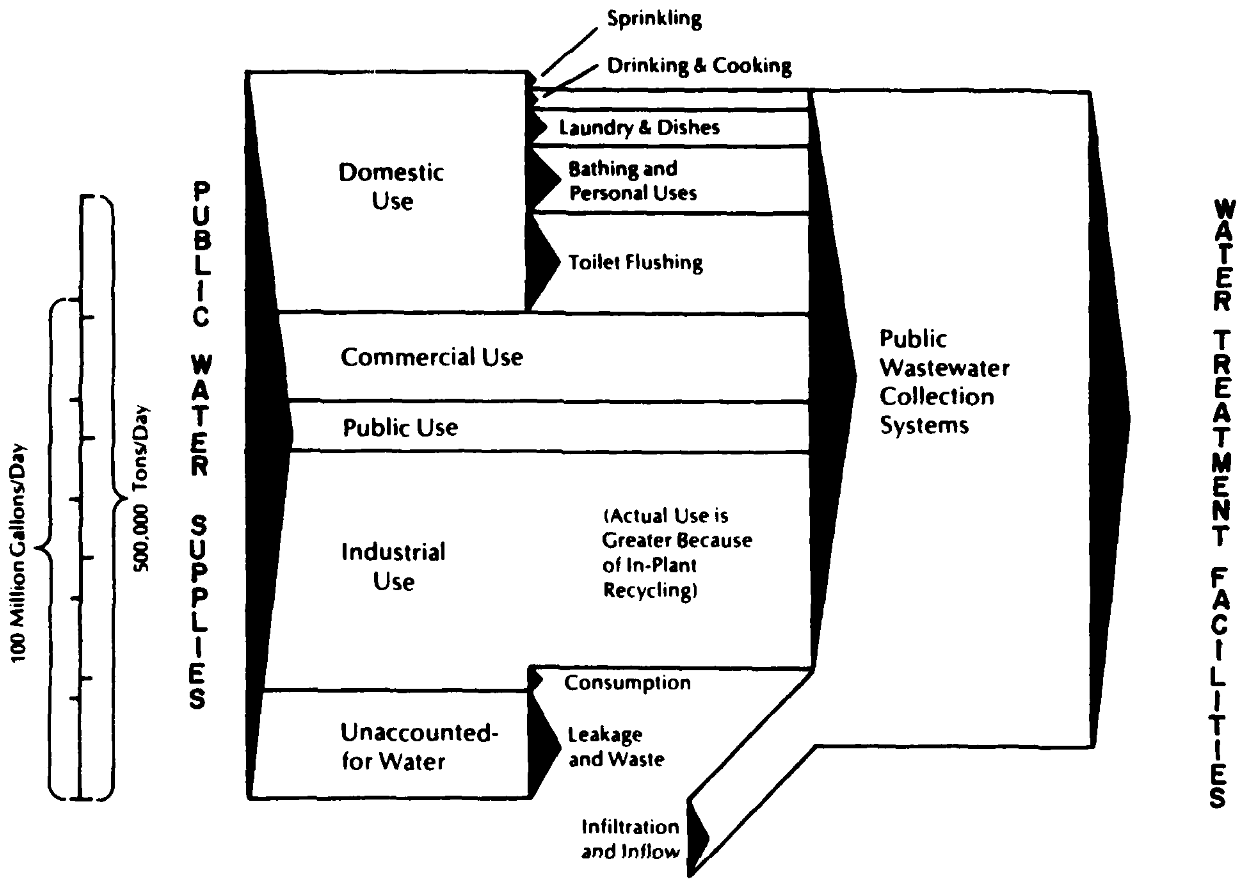


Figure 5-8. Components of a municipal water/wastewater system. (25)

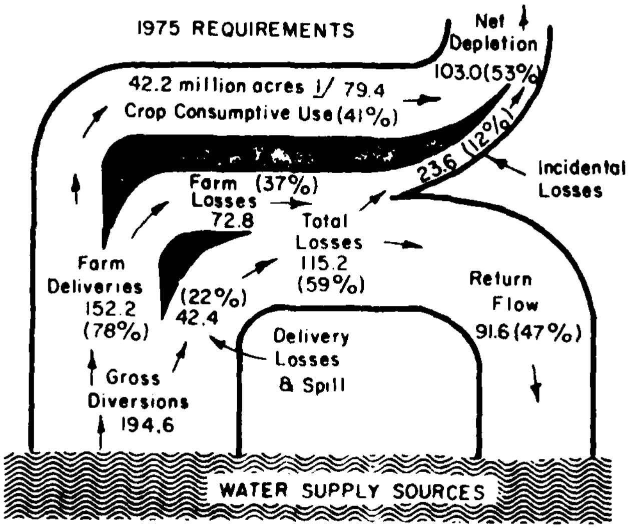


Figure 5-9. Schematic of irrigation components. (48)

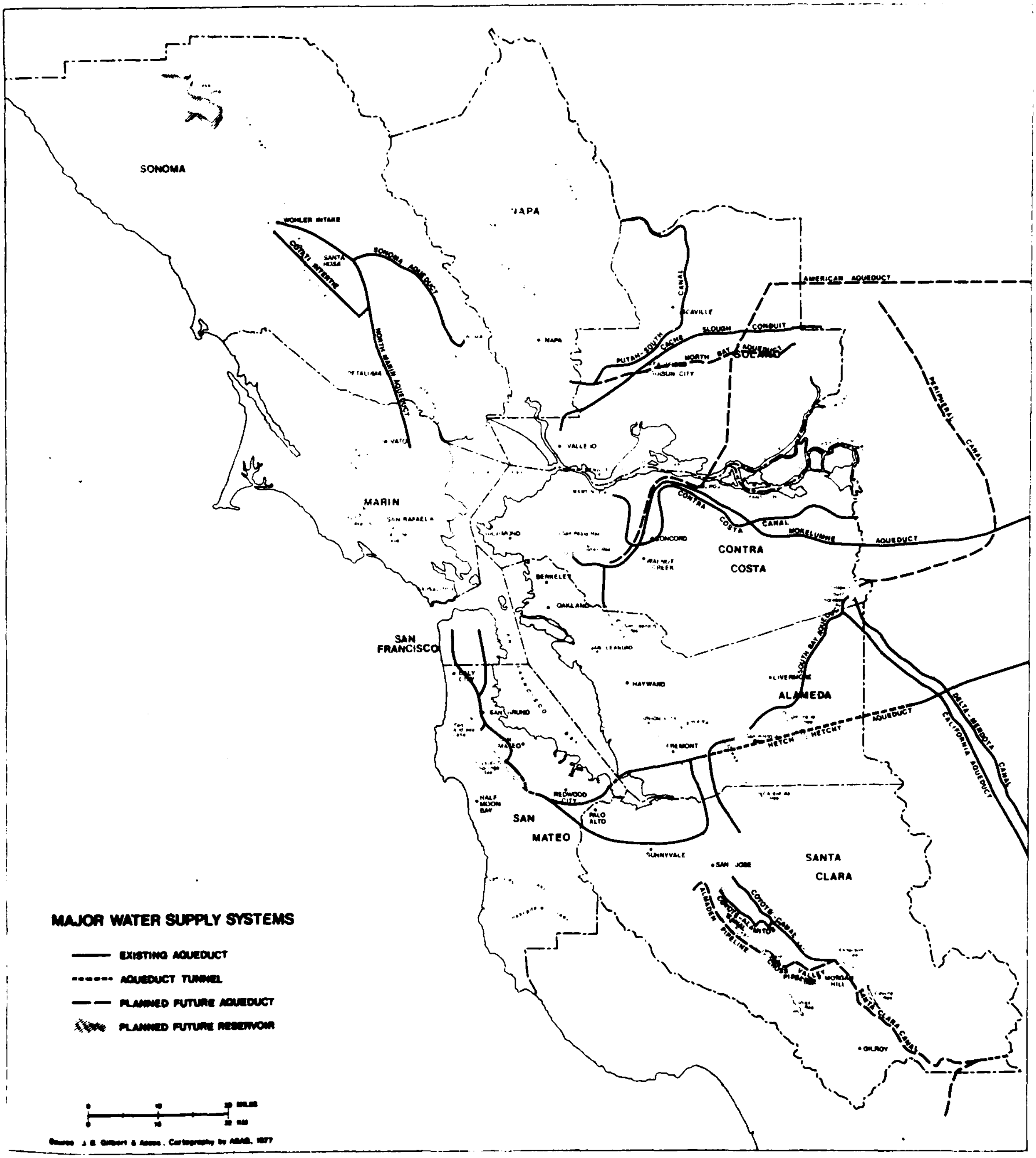


Figure 5-10. Water supply system components. (12)

SURFACE WATER SYSTEM

Inputs and Outputs
(Acre-Feet)

INPUTS	67	68	69	70	71	72	73	74	75	76	77
Mainstream Flow/Rio Grande*	603,531	901,924	1,183,144	836,024	594,879	479,421	1,480,349	511,823	1,121,225	721,897	290,753
Tributary Inflow	43,201	55,711	79,955	36,353	28,270	28,543	127,792	20,294	85,188	19,258	18,012
Precipitation/Runoff/ Ephermeral Channels	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
San Juan-Chama Imports					14,690	20,460	0.00	32,390	36,500	23,320	126,040
Riverside Drains**	132,000	124,000	144,000	137,000	112,000	112,000	168,000	152,000	177,000	193,000	164,000
Sewage Return Flow City of Albuquerque	27,706	27,939	29,180	29,588	32,290	33,975	33,107	38,119	39,217	44,803	43,111
Others	2,953	3,231	3,718	3,225	3,477	3,805	3,559	4,540	4,650	4,560	5,053
TOTAL	849,391	1,152,805	1,479,997	1,082,190	825,606	718,204	1,852,807	799,166	1,503,780	1,046,838	686,969
OUTPUTS											
Surface Water Diversion	328,860	310,270	358,870	343,520	280,340	279,160	420,650	380,690	442,010	482,260	411,170
Evaporation from Rio Grande	45,310	45,310	45,310	45,310	45,310	45,310	45,310	45,310	45,310	45,310	45,310
Channel Seepage	?	?	?	?	?	?	?	?	?	?	?
Pumping Depletion***	39,435	38,527	34,642	35,759	40,783	41,957	38,532	45,169	38,142	44,487	41,071
Surface Discharge/Outflow	411,127	726,864	1,036,431	709,684	448,094	392,739	1,464,832	394,008	1,116,913	541,466	216,996
TOTAL	824,732	1,120,971	1,475,253	1,134,273	814,527	759,166	1,969,324	865,177	1,642,375	1,113,523	714,547
Difference	24,659	31,834	4,744	-52,083	11,079	-40,962	-116,517	-66,011	-138,595	-66,685	-27,578

* Stream gaging records adjusted to include surface water diverted into Cochiti Eastside and Main Canals above the gage.
** 75% of irrigation infiltration + 10% direct return of diverted surface water (See surface water diversion, p 2-39).
*** Gross depletion from Mesa and Valley production combined (see Table in Appendix II-3).

Figure 5-11. Water balance of surface water system, AGUA study, Albuquerque, New Mexico. (39)

presentation of the water balance conducted in Albuquerque, New Mexico. It effectively presents eleven years of detailed information on the surface water system. A similar table was prepared for the ground water system. Notice the use of footnotes and text references. These aid the reader in tracing the summary data back to detailed explanations in the text and provide useful explanations as to how various data were derived. Note also that the result of the water balance was identified as a difference between input and output. The text discusses reasons for the difference.

Although tables are effective for report presentations, other types of presentations, particularly charts and graphs, may be more applicable for public presentations. As previously noted, they allow the viewer to easily make visual comparisons between components and to readily observe trends.

SECTION 6

STUDY MANAGEMENT

FACTORS AFFECTING REQUIRED RESOURCES

The resources (personnel, time, and money) required to accomplish a water balance are primarily determined by three factors: 1) availability of data to quantify supply and use of water resources within a study area; 2) complexity of the hydrologic and institutional systems; and 3) the purpose for which a water balance is to be conducted.

Data Availability

Study managers should assess the availability of water supply and use data prior to the preparation of time and cost estimates. The availability of data is directly related to study effort as well as to reliability and accuracy of study results. The collection and organization of data can be expected to account for 50 to 70% of the required effort to accomplish a water balance.

State water resource agencies and local offices of the U. S. Geological Survey, the Water and Power Resource Service and the Corps of Engineers should be contacted to determine the availability of data within the study area from these sources. The collection of data in states which have major water resources agencies such as California, Illinois, and Texas, may be a relatively minor task as the state agencies may have collected and organized most of the available data.

Although generalizations are only appropriate on the average, the following observations are offered to provide insight for study managers to estimate the effort required to collect data for water balance applications:

1) Surface water data are commonly more available than ground water data.

2) Supply and use data are generally more available in regions in which competition for water resources is high.

3) Supply and use data are easier to collect and more reliable in urban regions than in rural regions.

4) Data are easier to collect in regions which have large water users or suppliers than in regions which have a great number of small users or suppliers.

Complexity of Data

The complexity of the hydrologic systems and water management institutions has a significant impact on the effort required to accomplish a water balance. Complex hydrologic systems require more components and a more thorough understanding of the water resource system. A water balance for a region with numerous purveyors usually requires more time for analysis, since available data collected by the various institutions may represent different time periods, may be collected at unequal intervals, may be recorded in different units and/or may be organized in inconsistent categories.

Study Purpose

The purpose for which a water balance is being conducted has a major impact on the resources required for its completion. A water balance determination which is to be made in conjunction with a water supply study can utilize the data collected for water supply analysis. In this instance 50 percent or more of the study effort, the data collection, and organization portion will be accomplished as a part of the water supply analysis. Conversely, a water balance study which cannot use previously collected data will cost proportionately more.

PERSONNEL REQUIREMENTS

The primary personnel requirement for a water balance study is a water resource professional who is familiar with the use of water within a study region. The professional may be an engineer, hydrologist, geologist, or planner. Technicians, student aids, and draftsmen, under the guidance of the professional, may be utilized to collect and organize data and to prepare tables and presentation aids.

TIME AND COST REQUIREMENTS

The following table summarizes the time and costs associated with various types of water balance applications. Cost data are based on a assumed cost of $5,000 per month for a water resource professional with minor technical and clerical support.

Time and Cost Requirements for Water Balances

Water Balance Application	Simple System	Complex System
In conjunction with a water supply study	$ 5,000 (1 month)	$10,000 (2 months)
Water balance study (alone)	$10,000 (2 months)	$40,000 (8 months)

IMPACT ON PLANNING STUDIES

The determination of water balances will be an aid in planning studies in two important areas: water supply project formulation and water conservation analysis. Since water balances provide a framework to examine and understand all significant aspects of a region's water resources, they will aid in selection and formulation of water supply projects. Water balances are particularly useful for water conservation analysis since application of conservation measures requires a thorough knowledge of water use and the linkages between supply-use components.

The determination of water balances as a regular part of water supply investigations will in addition, provide state and local agencies with a more complete understanding of water supply and use within their region. It is anticipated that in most instances this type of analysis and information would be otherwise unavailable.

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APPENDIX I

FINDINGS FROM REVIEW OF SELECTED WATER SUPPLY STUDIES

A number of completed water supply studies, each of which developed water balance data to some degree, were reviewed during the preparation of this guide manual. Only one explicitly prepared a water balance as part of the study (Albuquerque Study). The others collected various supply and use data but the collection was not complete or it was not presented as a water balance. Even so, review was helpful both in developing the general method of computation and in selecting major purposes of water balances. Results of the review are briefly summarized below for each study.

In addition to examining a number of studies in detail, the literature was searched for research and other reports on water balances. The publications found are listed in the bibliography. Many of these publications dealt with a "scientific" water balance where the occurrence of water is traced through the hydrologic cycle.

Metropolitan Washington Area Water Supply Study for the Potomac Water Users, prepared by the U. S. Army Corps of Engineers, Baltimore District, 1979. (41)

The first purpose of this study was to identify water supply problems in the Metropolitan Washington Area (MWA), most of which result from variable flows in the unregulated Potomac River and storage depletion in local reservoirs. The second purpose of the study was to formulate plans for meeting the area's water supply needs, and to incorporate water conservation into the various alternatives. Part of the study involved estimation of future water demands based on economic and population projections; for this reason, the Washington,

D. C. Standard Metropolitan Statistical Area (SMSA) was chosen as the study area. Water supply problems were identified in part by a water balance type of hydrologic simulation which utilized historical drought period for supply conditions and a future period for water use. Monthly supply and use data were employed since the variability of the supply system and seasonal fluctuations in demand were important. Incorporation of water conservation into water management plans necessitated quantification of water use in various sectors. Types of uses quantified included residential, commercial, industrial, and municipal. Although ground water supplies exist in the study area, little ground water data were presented in the study because use of this resource is currently negligible.

Report on Water Conservation Reuse and Supply, San Francisco Bay Region, prepared by J. B. Gilbert and Associates, 1978. (12)

Purposes of this study included collection of information on water supply agencies in the San Francisco Bay Area, projection of water demands, and development of water conservation measures. Water use data was widely scattered since 83 distribution agencies serve the Bay Area. In addition, data compiled by the Association of Bay Area Governments (ABAG) were used for water demand projections. Therefore, the institutional boundaries of ABAG's nine-county region were chosen to define the study area instead of hydrologic boundaries. Water supplies to the area involve eight separate systems, including ground water, numerous local reservoirs, and several aqueducts from reservoirs outside the study area. Because the supply system is complex, variability of each component was not addressed in detail. The study focused instead on water use, detailing information on purveyors and types of uses in order to identify water conservation opportunities.

Roberts Tunnel Collection System Eagle-Piney/Eagle-Colorado Water Study, prepared jointly by Parsons, Brinckerhoff, Quade and Douglas, Inc. and Forrest and Cotton, Inc., 1974. (29)

The purpose of this study was to recommend plans for the continued integration of the Denver Board of Water Commissioner's water appropriations on the Eagle and Piney Rivers with various water supply systems. The study included completion and evaluation of records and other data pertaining to water availability in the Eagle and Piney River basins. Hydrologic boundaries of the two river basins were chosen to define the study area. A water balance type of simulation model was developed to determine water availability. The model utilized a quarter-monthly level of detail because both water supply and use fluctuate rapidly. Runoff in the river basins peaks within a three-month period due to snowmelt, resulting in a swift rise and fall of the hydrograph. Water use, which is largely agricultural, is influenced by rainfall, temperature, and calls from downstream users with senior water rights. A computer model was necessary because the time-dependent interrelationships between supply and use were too complex for a simple balance-sheet approach, especially where stream gage data were lacking. Furthermore, the model facilitated the manipulation of large quantities of data. In addition to determining water availability at any given location, the model was used to estimate virgin streamflows. Generated data extended streamflow records and permitted testing of the effects of proposed projects on water availability.

New Jersey Water Supply Master Plan, being prepared jointly by Havens and Emerson; Parsons, Brinckerhoff, Quade and Douglas; Westwater, Gaston; Geraghty and Miller; and Water Resources Engineers. To be completed in 1980. (13)

One purpose of this study was to prepare plans for water resource development in five watersheds which are anticipating growth in the near future. Part of the study involved estimating water availability in these areas and evaluating the effect of proposed storage developments. Hydrologic boundaries of the river basins were chosen to define the five study areas. A surface storage water balance model was used to determine the relationship between size of proposed storage facility and expected delivery. Later, storage, average delivery, and reliability of delivery were correlated. A 50-year period of analysis was selected so that reasonable estimates of reliability could be developed. Monthly supply and use data were employed. A finer level of detail was not needed because surface water runoff is fairly evenly distributed on an annual basis, and water demands, largely due to municipal and industrial activities, do not fluctuate rapidly. Low flows were also simulated for the 50-year period, making it possible to estimate how often minimum streamflow requirements were met.

Cedar River Water Yield Study, prepared by the U. S. Army Corps of Engineers, Seattle District, 1979. (40)

The purpose of this study was to determine the 98% reliable Cedar River yield for municipal and industrial water supply at Landsbury, Washington, under existing conditions and with proposed modifications to the Seattle Water Department Cedar River Project for flood control. Hydrologic models of the Cedar River Basin and Lake Washington were developed as a first step in the yield analysis. Hydrologic boundaries of the basin and lake were chosen to define the study areas. Water balance equations used in the river basin model included typical components such as evaporation, precipitation, streamflow, seepage,

and reservoir releases. The model was calibrated and modified to accurately simulate conditions during several droughts. This allowed estimation of river flow under normal and drought conditions. Water balance equations of the Lake Washington model included several unusual components, such as lockage flow, fish ladder discharge, and salt water drainage. End-of-month lake elevations were calculated to show the effect of excess yield diversions and high future lockage demands on lake levels.

<u>Albuquerque Greater Urban Area Study, Appendix III: Water Supply</u>, prepared by the U. S. Army Corps of Engineers, Hydrologic Engineering Center, 1979. (39)

The purpose of this study was to assess the availability and use of water resources in the Albuquerque Greater Urban Area (AGUA). Hydrologic boundaries of the Middle Rio Grande basin from Cochiti Dam in the north to Bernardo in the south were chosen to define the study area. Water resources were examined in the context of separate surface and ground water balances which utilized average annual data for a period of 11 calendar years. Although known to be highly interrelated, the surface and ground water systems were artificially separated for ease of data collection and clarity of water balance presentation. Both magnitudes and interrelationships of components were investigated. Inflows and outflows to and from the surface water system did not balance, although relative magnitudes of components were fairly accurate. It was concluded imprecision must be expected when averages and constant percentages which do not account for climatic variations are used. Furthermore, estimates from gathered data were required when study area and data-base boundaries did not coincide. Results of the ground water balance showed increasingly negative values for change in storage which paralled increasing ground water withdrawals. This indicated the ground water resource

is being depleted, and the ground water system is sensitive to pumpage by the City of Albuquerque. In addition to giving quantitative results, the water balances illustrated interactions among components of the hydrologic systems and pointed out significant gaps in the data base.